nationalgrid

Stage 01: Workgroup Report

Grid Code

High Wind Speed Shutdown Workgroup Report

This report reviews the work of the High Wind Speed Shutdown Workgroup established by the Grid Code Review Panel at the May 2012 meeting.

What stage is this document at?

01	**Workgroup Report**
02	Industry Consultation
03	Report to the Authority

This document contains the findings of the Workgroup which formed on 11 September 2012 and concluded on 11 June 2013.

Published on: **03 July 2013**

The Workgroup recommends:

The Workgroup recommends that no changes are required to the Grid Code at the current time. It is recommended that wind generators provide National Grid with data on actual High Wind Speed Shutdown Events in the post operational phase using the provisions set out in OC7 and OC10. It is further recommended that National Grid should use this data to improve its modelling of the probability and consequence of HWSS. It is also recommended that the GCRP review in two years (or earlier should further evidence become available), whether this topic needs to be revisited.

High Impact:

None identified

Medium Impact:

None identified

Low Impact:

None identified

Contents

Any Questions?

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About this document

This document is a Workgroup Report which contains the discussions and recommendations of the High Wind Speed Shutdown Workgroup.

Document Control

Version	Date	Author	Change Reference
1.0	03 July 2013	National Grid	Final Workgroup Report

1 Executive Summary

1.1 Summary

1.1.1 In general, most individual wind turbines will shutdown when wind speeds average over 25m/s (approximately 56 miles per hour) for a preset period or for a gust of around 35m/s (approximately 79 miles per hour) although the precise implementation of this behaviour (averaging period and gust shutdown wind speed) varies between different manufacturers and models of turbine. This phenomena is known as high wind speed shutdown (HWSS). It is acknowledged that new designs and control systems have been and are being developed by manufacturers to reduce the rate at which wind turbines shut down once the average wind speed exceeds 25m/s

1.1.2 National Grid expressed concern that significant volumes of wind generation could disconnect from the system over a short period of time due to HWSS if wind speeds across a large geographic area were to suddenly rise above 25 m/s.

1.1.3 National Grid also expressed concern that significant volumes of wind generation could subsequently reconnect over a short period of time when wind speeds abate to 'normal' operating speeds.

1.1.4 The Grid Code Review Panel set up this Workgroup to investigate the probability and significance of these issues and whether some form of HWSS signal should be developed.

1.1.5 In general, wind turbines are designed to commence disconnection or reduce active power output at wind speeds in excess of 25 m/s in order to protect themselves against excessive mechanical loading. In order to manage System Frequency with increasing amounts of wind generation connected to the System, National Grid needs to establish the probability and likely consequence of wind turbine disconnection due to high wind speed in order to plan for such Events. It also needs to understand the shutdown and reconnection behaviour of wind turbines. Based on the current forecast wind growth (National Grid **UK Future Energy Scenarios 2012,** Gone Green or Accelerated Growth Scenarios) where the total installed wind generation capacity by 2020 is projected to exceed minimum demand levels, this issue causes some concern to National Grid as System Operator.

1.1.6 This potential for large amounts of wind power to disconnect and subsequently reconnect, with large ramp rates in a manner which is difficult to predict with present tools, could present significant challenges in the control of System Frequency. With the significant growth in wind generation, especially offshore (where the average wind speeds can be higher), HWSS Events could become more frequent and potentially greater in magnitude. However this issueis likely to be mitigated by new wind turbine designs and control systems that reduce the likelihood of a sudden HWSS Event. From a System Operator perspective, control of System Frequency is likely to become even more challenging through increased displacement of synchronous generation, lower system inertia and greater uncertainties in wind generating output. The impact of lower system inertia is being addressed in part by GC0035 Frequency Changes during Large Disturbances and their impact on the Total System, while the work of the Power Available Workgroup will help address the challenges associated with greater uncertainties in wind generating output.

1.1.7 The HWSS Workgroup examined the challenges faced by the System Operator during HWSS Events and the data currently recorded by wind turbines that could help the System Operator forecast the probability and likely impact of HWSS Events and subsequently manage the consequences efficiently. This data ranged from a post event analysis of the behaviour of an entire wind farm to the individual signals from each turbine as it shuts down.

1.2 Workgroup Recommendation

1.2.1 At the current time, based on the data presented by Workgroup members, HWSS Events normally occurred infrequently i.e. less than once a year, and over a timescale of hours rather than minutes, as a weather front moves across a region, affecting first those turbines within a particular wind farm which are at the most exposed locations.

1.2.2 The consensus of the Workgroup was that currently HWSS Events are too infrequent, and of insufficient consequence, to justify modification to the Grid Code.

1.2.3 The Workgroup agreed that there was benefit to the industry in National Grid being able to improve its forecasting ability in respect of HWSS Events. The Workgroup suggested that National Grid should obtain HWSS information from Power Park Module owners in the post operational phase through Grid Code OC7 (Operational Liaison) and OC10 (Event Information Supply).

1.2.4 The Workgroup recommends that the Grid Code Review Panel review the issue in two years time, or earlier should further evidence become available, and consider whether they feel there is any need for any further action. The Workgroup notes that during the intervening two year period National Grid will continue to produce internal forecasts of probability of HWSS Events, and will seek to improve the accuracy of these forecasts with the help of data provided by Power Park Module owners.

2 Purpose & Scope of Workgroup

2.1 Background

2.1.1 At the 16th May 2012 Grid Code Review Panel (GCRP), National Grid presented the concepts of HWSS where it was proposed that a Workgroup should be established to examine whether the development of a HWSS signal from wind generation is required for system operation purposes (minutes 2500 to 2506).

2.1.2 The GCRP agreed that this issue required further investigation. Draft Terms of Reference were presented by National Grid at the 16th May 2012 GCRP (minute 2500). Modified Terms of Reference were agreed at the 18th July 2012 GCRP following comments from a GCRP member (minutes 2504, 2589, 2590). The GCRP also recommended that, for efficiency, it may be appropriate to hold a joint Workgroup to discuss High Wind Speed Shutdown and Power Available, whilst ensuring that the two sets of terms of references were fully addressed.

2.1.3 A copy of the full Terms of Reference can be found in Annex 1.

2.2 Scope

2.2.1 The Scope for the HWSS Workgroup is:

The Workgroup shall consider and report on the following:

(a) Using information currently available, quantify the potential change in risk to the Total System presented by the need to protect wind turbines at high wind speeds by:

- (i) examining the potential volumes of affected generating capacity over time;
- (ii) reviewing existing information on the response to high winds over individual windfarms and the GB and Offshore wind fleet as well as relevant international data; and
- (iii) comparing high wind shut down power infeed changes to other power infeed changes in the power system including large infeed losses - generator trips, HVDC trips – and large changes in power flows – e.g. interconnector loading changes.

In the context of this risk, the Workgroup will:

(a) Review the actions that National Grid may need to take to manage high wind conditions given the risks quantified above;

(b) Review the information that is currently available to wind farm operators on the High Wind Shutdown status of wind turbines and assess the value that provision of this information to National Grid will yield;

(c) Identify additional items of information which could be of benefit and assess the value of providing these to National Grid;

(d) Assess the value of setting out requirements to reduce the impact of High Winds by limiting that rate at which turbines across a windfarm disconnect and reconnect; and

Timeline

Workgroup Meeting Dates

M1 - 11 September 2012

M2 - 09 October 2012

M3 - 08 November 2012

M4 - 10 December 2012

M5 - 12 February 2013

M6 – 14 March 2013

M7 – 1 May 2013

M8 – 11 June 2013

(e) Determine an appropriate implementation timescale for any new requirements.

The Workgroup will also:

(a) Take account of other industry developments with respect to wind farms in information provision and operation; and

(b) Take account of relevant international practice and the approach taken in European Code Development.

3 The Challenge

3.1 Introduction

3.1.1 The natural geography of the British Isles, its coastlines and high average wind speeds, particularly offshore, provide an excellent opportunity to exploit wind power as a valuable resource.

3.1.2 Most wind turbines are designed to shutdown when wind speeds average over 25m/s (approximately 56 miles per hour) for a preset period or for a gust of around 35m/s (approximately 79 miles per hour) in order to protect the Generator and turbine structure, although the precise implementation of this varies between different manufacturers and turbine type. National Grid as System Operator of the GB Transmission System is therefore keen to assess and anticipate both the probability of Events comprising the near simultaneous high wind speed shutdown of many wind turbines (HWSS Events) and the impact they could have on managing System Frequency.

3.1.3 Following the announcement of the Crown Estate's Round 3 Offshore Wind Farm zone development agreements, there is a trend for increasing numbers of large offshore wind farms connected via cables directly to the Onshore Transmission System. In the case of offshore wind farms, the probability of weather related Transmission faults is believed to be lower, but the naturally greater wind resource offshore increases the probability of wind turbine shut down due to high wind speeds.

3.1.4 Significant growth is forecast in the volumes of Offshore Wind Generation over the next few years (approximately 14GW by 2020), in addition to 11 GW of Onshore Wind Generation by the same date (National Grid **UK Future Energy Scenarios 2012,** Gone Green Scenario). With this large volume at theoretical risk of HWSS, National Grid as System Operator needs to develop a better understanding of the probability of HWSS Events, and the likely consequences of such Events in order to ensure system security at the lowest possible cost.

3.2 Disconnection

3.2.1 Wind turbines are designed to operate within a very specific range of wind speeds. Generally they will automatically start generating at hub height wind speeds between 3 – 4 m/s (7 – 9 mph), reach rated output typically in the range of between 11 – 14 m/s, (25 – 31 mph) and begin to disconnect or reduce power at wind speeds above 25 m/s (56 mph). In this latter range the turbines may disconnect to protect themselves against excessive mechanical loading. In order to manage the increasing amount of wind generation connected to the Transmission System, National Grid would need to assess the probability and likely impact of wind turbine disconnection due to high wind speed in order to plan for such Events. Based on the current forecast, wind growth where the total installed wind generation capacity by 2020 will exceed minimum demand levels, this issue causes some concern to National Grid as System Operator.

3.2.2 Generally, wind turbines which use a high wind speed shutdown protection strategy (presently the most common strategy) maintain rolling 10 minute average values of wind speed. When these rolling averages exceed a high wind speed cut out threshold value (typically between 25 m/s and 34 m/s) the turbines will shut down. The shutdown characteristics will vary from manufacturer to manufacturer and turbine to turbine, but in general, wind turbines will have a range of shut down strategies with shorter averaging periods for higher wind speed conditions e.g. rolling 1 minute averages. Some wind turbines do not use a high wind speed shutdown protection strategy and instead gradually reduce active power output as wind speed increases above a maximum threshold (similar to the above high wind speed cut out threshold value). Such turbines also have a high wind speed cut out value but it may be so high that it is rarely encountered e.g. 41 m/s (92 mph). However, it is acknowledged that wind turbine control system design and behaviour at wind speeds in excess of 25m/s continue to evolve as some manufacturers attempt to avoid a sudden drop in active power output.

3.2.3 Based on the current volume of wind generation installed, there is little evidence to suggest the frequent, sudden and complete shut down of a total wind farm or the shut down of wind farms over a wide area due to HWSS Events. However there have been cases of individual wind turbines within a wind farm shutting down due to high wind speed and more limited cases where the total wind farm has shut down over a period of time due to a HWSS Event. As the volume of offshore wind generation is expected to grow significantly in the future National Grid is concerned at the potentially increasing probability of HWSS Events. Such Events could lead to difficulties in managing system frequency when there is a sudden drop in active power output or a sudden increase in active power output when generation reconnects following abatement of the wind speed. From a System Operator perspective, control of system frequency becomes even more of a challenge through increased displacement of synchronous generation, lower system inertia and greater uncertainties in wind generating output. These challenges were the subject of a separate Grid Code Workgroup.

Frequency Response Workgroup – Available at:-
http://www.nationalgrid.com/NR/rdonlyres/9A0A6194-170F-4A15-9F9D-A72711CC2B7B/58504/FrequencyResponseWorkgroupReportv11.pdf

Frequency Response Technical Subgroup
http://www.nationalgrid.com/NR/rdonlyres/2AFD4C05-E169-4636-BF02-EDC67F80F9C2/50090/FRTSGGroupReport_Final.pdf

3.3 Reconnection

3.3.1 A wind turbine which has shut down due to a HWSS Event will typically remain disconnected (depending upon manufacturer) until the restart criterion is satisfied e.g. where the 10 minute average wind speed drops to 22 m/s (approximately 50 mph). Then automatic reconnection and ramping back to full power will occur.

3.3.2 The impact of the above wind turbine post HWSS restart strategy is that, unless controls are implemented, a significant volume of MW could appear from the wind farm over a short time scale and without warning. Whilst BC1.A.1.1 of the Grid Code places obligations on BM Units to limit their ramp rates for active power changes exceeding an aggregated total of 300MW at a Grid Entry Point or Grid Supply Point by a single BM Participant, a wind turbine post HWSS restart still necessitates the pull back of other generation to maintain System Frequency. As the size of individual wind farms (particularly offshore) increases, techniques may be required to mitigate sudden changes in MW output resulting from post HWSS Event wind turbine reconnections..

3.4 Current information provision

3.4.1 The following information is provided by wind farm BM participants.

3.5 Physical Notification (PN)

3.5.1 PN is used as the basis for accepting bids and offers from Balancing Mechanism (BM) participants. PN is also used by National Grid to calculate the total predicted generation on the system

3.6 Maximum Export Limit (MEL)

3.6.1 MEL is an indication of the maximum generation output available which could be provided by a BM unit. National Grid uses the difference between Final Physical Notification (FPN) and MEL as a calculation of additional generation available from synchronised units (‘headroom’). National Grid must always carry sufficient headroom to meet its response and reserve requirements . MEL is also used in the calculation of frequency response.

3.7 Dynamic Parameters

3.7.1 Dynamic parameters include run up and run down rates, notice to deviate from zero, notice to deliver bid/offers, minimum zero and non-zero time, stable export and import limits and maximum delivery volume/period. These parameters are intended to allow the BM unit to provide the System Operator with information to understand the physical dynamics of the BMU and National Grid takes into account this information when issuing bid offer acceptances.

3.7.2 Power vs Wind Speed Curve, Wind Speed, Wind Direction - These data items are used along with metered output data to provide and improve wind generation forecasts. This is done using a dual model where the power curve is represented in two parts. The first part represents normal operation where the wind speed is less than the cut-out speed. The second part represents the behaviour of the power curve at and beyond the cut-out wind speed. This is shown in Figure 1

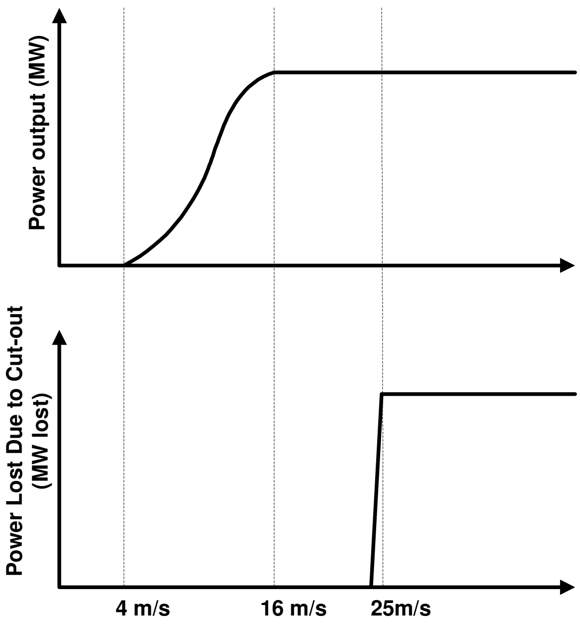

Figure 1: Two part model representing normal operation and MW lost

3.7.3 The above chart is a simplified representation of the behaviour of a typical wind turbine (which uses a high wind speed shutdown protection strategy) in response to wind speeds from a particular wind direction. It illustrates the point that when the wind speed forecast is near to the cut-out speed of the wind turbine then a small wind speed error (e.g. due to variation in wind speed across a wind farm caused by site topography) can result in a large error in wind power forecast that is equal to the rated capacity of the turbine.

3.8 Metered Output

3.8.1 Metered output from all generators is used in real time as part of National Grid's overall management of generation to balance demand. Metered output is also important to National Grid to allow power flows on the Transmission System to be managed, in particular in areas where there are transmission constraints.

4 Addressing Terms of Reference

In this section, each specific item in the Scope section of the Terms of Reference is addressed in turn.

4.1 Potential volumes of affected generating capacity over time

4.1.1 The projected amount of renewable generation that are contracted to connect to the system within the next 5 years can be shown in Figure 2 below ('Contracted future renewable generation') with the majority of the new connections being from wind farms. This chart is based on data in National Grid's Transmission Entry Capacity (TEC) Register

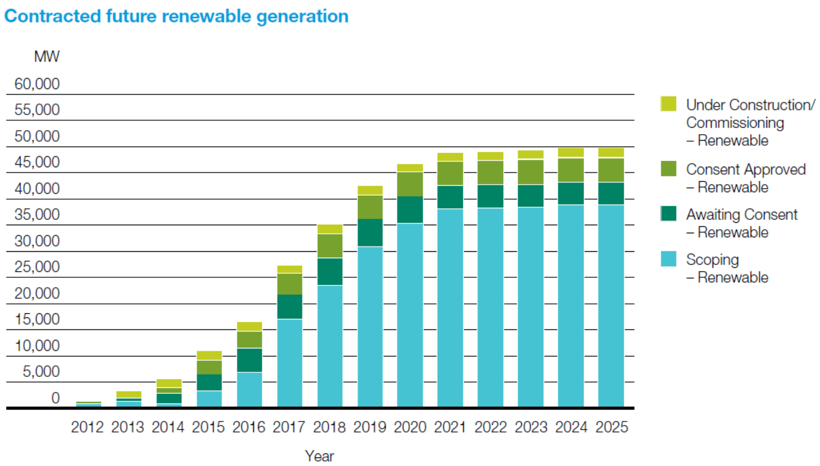

Figure 2 - Contracted Future Renewable Generation

4.2 Existing information on the response to high winds

4.2.1 The advice from Workgroup members was that there have only been a small number of instances in the UK where an entire wind farm has shut down due to a HWSS Event, although it is more common for individual turbines within the wind farm to shut down due to high wind speed. The precise conditions required for a turbine to trip on HWSS vary between manufacturers, but are typically wind speeds of 25 m/s (56 mph) sustained for a preset period or for gusts of 35 m/s (79 mph). It was pointed out that a wind speed of 25 m/s corresponds to Storm Force 10 on the Beaufort Scale, and 35 m/s to Hurricane force 12. It should be noted that the Beafort Scale relates to wind speed measurements at 10m above sea level, while wind speed used to determine HWSS is usually measured at the turbine hub, anything up to 100m above sea level. At any given instant, the wind speeds at each turbine location within a wind farm will differ due to the effects of local topography and the wakes from other wind turbines. Therefore it is very rare for HWSS conditions to exist across an entire wind farm, let alone multiple large wind farms, at the same time. It was noted that there have been examples in Europe where whole wind farms shut down due to high wind speed.

4.3 Comparison of high wind shut down power infeed changes to other power infeed changes in the power system

4.3.1 Under the Security and Quality of Supply Standards (SQSS) National Grid is required to carry sufficient response to allow for an instantaneous infrequent infeed loss of up to 1320 MW. The SQSS is due to be revised in April 2014 which will result in the infrequent infeed loss being increased to 1800MW. Whilst National Grid as System Operator will not be required to carry sufficient response to cater for an 1800MW loss in April 2014, it will mean that connection designs from April 2014 will be permitted where up to 1800MW of Generation could be lost to a credible Transmission System Fault. At the time of writing, National Grid does not expect the volume of response carried to exceed 1320MW until the end of 2015, although this could change depending on the frequency and volume of future connection applications. The view of the Workgroup was that it is unlikely that HWSS would ever result in a near instantaneous loss of this magnitude. Losses due to HWSS will be more gradual, as weather fronts move over wind farms, causing a few turbines at a time to trip over a period of minutes or hours rather than seconds.

4.3.2 This type of behaviour is more analogous to the gradual loss of gas fired generation that could occur in the event of a major interruption to gas supplies from the UKCS. While this type of Event often attracts significant media interest, they can usually be managed in operational timescales, albeit at potentially significant cost.

4.4 Actions that National Grid may need to take to manage high wind conditions

4.4.1 The options for managing HWSS can be split into different aspects. Broadly these are:

(a) Forecasting a potential Event (expected magnitude, time of onset and clearance, associated uncertainties)

(b) Understanding / restricting the behaviour of wind farms during such an Event

(c) The ability to control wind farm behaviour or take mitigating actions.

Each area is discussed in turn below.

4.5 Forecasting a potential Event

4.5.1 National Grid currently receive operational metering data in the form of MW, MVAr, Wind speed and Wind Direction from many of the BMU wind farms on a per Power Park Module (PPM) basis (there may be several PPMs/BMUs within one wind farm). National Grid also purchases forecast wind speed and wind direction data. Forecasting the probability, magnitude and timing of HWSS is currently done using a dual model. The System Operator considers that further refinement in this area is necessary given the current levels of uncertainty in forecasting HWSS events (see Annex 2).

4.5.2 If the occurrence of HWSS could be accurately and confidently forecast, then other types of generation could be used to manage the Events. Unfortunately, the present quality of wind power forecasting data and in particular for forecasting HWSS Events can result in wind power forecasting errors of 1GW, which can be due to errors in either magnitude or timing of forecast high wind speed, or both. This has to be managed with short notice expensive generation. If more accurate forecasting was available then the volume of additional response and reserve held to cover the risk of HWSS could be reduced, hence reducing balancing costs.

4.5.3 A general principle with forecasting is that more measurement data leads to improved forecast accuracy. The trade-off being in the balance between measuring everything or measuring only those parameters that will lead to a significant improvement in the forecast accuracy. In practice, it is very difficult to determine which new data streams would yield this benefit without receiving the data on a trial basis and experimenting to see if a benefit can be achieved. At present only around 60% of wind farm output data is metered and available to the ENCC at Wokingham (typically Transmission connected wind farms throughout GB and Large Distribution connected wind farms in Scotland).

4.6 Understanding / Restricting the behaviour of wind farms during a high wind speed Event

4.6.1 Some wind turbine manufacturers have implemented, whilst others are developing control systems so that the reduction in MW output, as the wind increases beyond the cut-off speed is more gradual. This can increase the amount of energy that the turbines produce in high wind scenarios, as it allows turbines to stay connected for longer. It also has the benefit of making the behaviour of the turbines more benign and predictable from the perspective of the System Operator.

4.6.2 Work is ongoing in this area, mainly with manufacturers, and the main consideration is to enable greater energy production while maintaining the required 20+ year lifespan of the turbines.

4.6.3 The Workgroup discussions suggested that there may be patent issues with this option, and that further discussions would be necessary regarding whether this option, if taken forward, could be required generally and would apply retrospectively. One Workgroup member confirmed that those wind farms with wind speed ramp down have experienced a higher Annual Energy Production (AEP) as they don’t have to wait for wind speeds to reduce as much before resuming generation after a HWSS Event.

4.6.4 The system operator may be able to better optimise the management of High Wind Speed Shut down if the characteristics of individual wind farms in such circumstances were understood.

4.7 The ability to control wind farm behaviour or take mitigating actions

4.8 Pre-emptive Shutdown

4.8.1 Pre-emptive shutdown involves instructing wind farms off the system before they experience HWSS. This option would remove the uncertainty of if, when and by how much a wind farm may reduce active power output. This option is something that the control centre can action now with BOAs but is likely to be expensive, depending on the number of bids available.

4.8.2 The Workgroup suggested that this is a workable interim solution as it doesn’t require any system changes but recognised this would increase the costs to consumers of operating the system.

4.9 Bilateral Arrangements

4.9.1 Bilateral arrangements could be established to manage the behaviour of wind farms, either through automatic control arrangements / ramp rates or through despatch arrangements. This may be an effective way of reducing the probability and impact of HWSS Events on the system for a few high capacity wind farms, but application of this technique to a large number of lower capacity wind farms would present a large admistrative overhead, and would not necessarily be a viable solution for the control room in operational timescales.

4.10 Current actions to manage HWSS

4.10.1 National Grid currently provides an internal forecast of the probability of HWSS to the Control Room. This forecast is used to inform decisions on whether to take any action to mitigate the risk of HWSS. This could include procurement of additional response or reserve, or even in principle pre-emptive shutdown of a wind farm ahead of an anticipated HWSS Event.

4.10.2 The forecast methodology and limitations are discussed in more detail in Annex 2.

4.11 Information that is currently available to wind farm operators on the High Wind Shutdown status of wind turbines

4.11.1 Whilst the Workgroup recognised that the System Operator required information to manage HWSS Events, it was difficult to generalise the behaviour of wind farms as a number of variables can affect the shut down of turbines. This includes and is not limited to the following:

(a) Location of met mast to measure the wind speed – the wind speeds at the met mast and at each wind turbine will differ due to topographic and wake effects

(b) Wind direction – the correlations of met mast wind speed and wind speed at each wind turbine will vary with wind direction.

(c) For offshore wind farms, wind turbine layout will have an impact on which turbines are most likely to shut down.

(d) For onshore wind farms, local terrain issues such as hills or valleys will have a similar effect.

(e) Specific turbine control system – different manufacturers will have different tolerance levels and shutdown sequences when operating during high wind speed shut down conditions.

(f) Gusting and/or rate of increase of wind speed which may trigger shutdown via different criteria other than the commonly used 10 minute average criteria.

4.11.2 To demonstrate the different variables which can affect the shutdown of a wind turbine, the following graph in Figure 3 below was presented by a Workgroup member which was extracted from the 10 minute SCADA data from an onshore wind farm in Ireland:

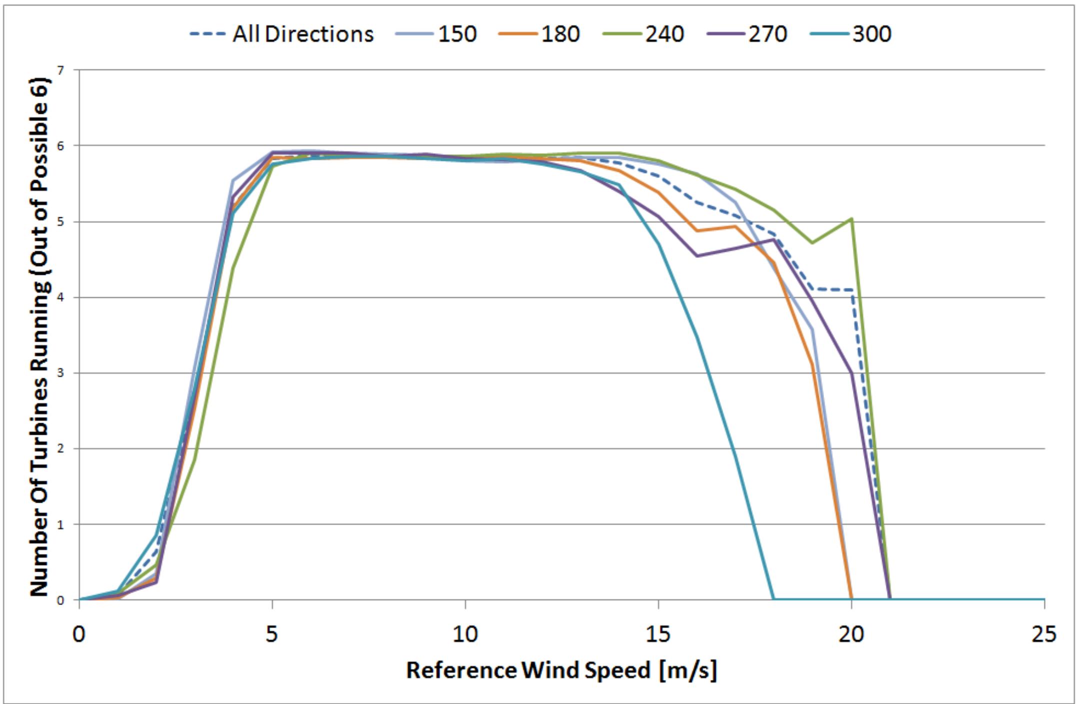

Figure 3: Operational turbines by wind speed by wind direction (Source RES)

4.11.3 From Figure 3 it is clear that it is not possible to use a single wind speed as a reference point for turbine shutdown as it varies depending on wind direction in conjunction with wind speed. Therefore, the Workgroup advised caution when attempting to model the behaviour of wind farms in HWSS scenarios.

4.12 Additional items of information which could be of benefit

4.13 The Workgroup discussed a number of additional items that could be of benefit.

4.14 Wind farm Profiling

4.14.1 The Workgroup discussed the potential profiling or "fingerprinting" of specific wind farms in order to analyse the probability of them shutting down in high wind scenarios. However, this requires historical data and analysis from each wind farm in order to build up a picture of their characteristics which is not a trivial undertaking as accuracy would depend on the level of granularity from each wind farm data set. It is worth noting that it is not known whether this method can successfully capture or manage HWSS Events but the Workgroup acknowledged that it remains a viable option pending further support from developers and manufacturers.

4.15 Shutdown Alarms

4.15.1 Wind farm control systems generally provide a wide range of alarm signals on a second by second basis. These include shutdown alarms which show when a turbine entered the shutdown state and when it returned to normal operation.

4.15.2 These shutdown alarms could be used to develop a "shutdown progression fingerprint" which in turn could be used for short term (0 to 3 hours ahead) forecasting.

4.16 MW data from each turbine

4.16.1 Wind farms operators will have output data from each individual turbine. The MW output data can be used to indicate whether a turbine is in a shutdown state. MW output data could also indicate; no wind, plant maintenance, Bid Offer Acceptance or trade, meaning it would need to be used in conjunction with other data.

4.16.2 The Workgroup discussions centred on whether it is easier to provide shutdown alarm data, or MW output data, and which is preferable. National Grid suggested both data sets are the most preferable outcome. The manufacturer representatives indicated that they store 10 minute average, maximum, minimum and standard deviation data forever, and during wind turbine shutdown events they record alarms and status changes with millisecond time stamps.

4.16.3 The Workgroup also discussed whether these options would be real time data or historical data. National Grid suggested that in the short term, any historical data would be an improvement as this could be stored and modelled to create a profile, then real time data could be submitted if or when relevant.

4.16.4 The Workgroup concluded that were a decision taken in the future to provide real time data to National Grid, then the shutdown signal is the easiest and most accurate. If the wind speed measurement from each turbine was also provided then it would create a detailed picture of what is happening.

4.16.5 The information which wind farms provide would need collating to be used for modelling. The Workgroup asked whether this is something National Grid should do or a third party?

4.17 Value of setting out requirements to reduce the impact of High Winds by limiting that rate at which turbines across a windfarm disconnect and reconnection

4.18 Restricting re-connection time

4.18.1 It is common practice in the industry for wind turbines to automatically re-connect and commence generation after a HWSS Event. This has the potential to cause problems in the Electricity National Control Centre if a significant number of wind turbines start generating in a short timescale because of the unexpected sudden increase in MW output. This issue becomes more complex to manage overnight when less flexible plant is available. It is not possible for National Grid to determine at the current time whether the rapid changes in wind generation that it currently sees are due to un-notifed HWSS Events or due to localised rapid changes in wind speed. Over the winter of 12/13 National Grid experienced drops of more than 700 MW in directly connected wind generation in a four hour period, an average of about five times per month.

4.18.2 At the present time BC.2.5.2. of the Grid Code, states;

*In the case of **Synchronisation** following an unplanned **De-Synchronisation** within the preceding 15 minutes, a minimum of 5 minutes notice of its intention to **Synchronise** should normally be given to **NGET** (via a revision to **Export and Import Limits**). In the case of any other unplanned **De-Synchronisation** where the **User** plans to **Synchronise** before the expiry of the current **Balancing Mechanism** period, a minimum of 15 minutes notice of **Synchronisation** should normally be given to **NGET** (via a revision to **Export and Import Limits**). In addition, the rate at which the **BM Unit** is returned to its **Physical Notification** is not to exceed the limits specified in **BC1**, Appendix 1 without **NGET's** agreement.*

4.18.3 In National Grid's experience, wind generation generally does not always notify the System Operator prior to re-connection following a shutdown. The Workgroup recognised that the terms synchronise and de-synchronise are not sufficiently explicit for wind generation and there is some confusion as to how BC2.5.2 applies to wind generation. . However National Grid's view is that the intention is that if a generator experiences a HWSS Event which causes partial or complete reduction in MW output then the generator should not increase output unless the Electricity National Control Centre has granted permission. This notification could be done via EDL link rather than by telephone.

4.18.4 The Workgroup noted that unless appropriate controls are mandated, restricting the increase of a wind farm's MW output for a certain length of time could result in faster ramp rates as many turbines could be in a post HWSS state rather than a stepped increase as each turbine reconnects immediately as they individually exit the HWSS state. However it was noted that the requirements of BC1.A.1 of the Grid Code would still apply.

4.19 Ramp rate restrictions

4.19.1 Currently the Grid Code (BC1.A.1) applies limits to ramp rates for a single BM Unit (or the aggregate Physical Notifications for a collection of BM

Units at a Grid Entry Point or Grid Supply Point or to be transferred across an External Interconnection, owned or controlled by a single BM Participant for active power changes exceeding 300MW. It is possible that the aggregate output of a number of <300MW BMU wind farms all acting nearly simultaneously in response to wind conditions may result in very large ramp rates. There are currently no clauses in the Grid Code that apply to a group of BMUs owned or controlled by different BM Participants acting together but with each BMUs individual change in output being less than 300MW. Under this option, one approach which could be considered is that a group of BMUs could be informed by National Grid that they are acting in concert to cause their aggregate output to exceed ramp rate limits specified in a new Grid Code clause or a modified BC1.A.1.1 and they can be instructed to safeguard the system frequency. The group discussed whether this should be an emergency instruction, where no costs should be borne by the consumer or whether wind farms should be compensated.

4.20 Is it cheaper to have a controlled shutdown (instigated by the wind farm) or to have the SO dealing with an unpredictable shutdown?

4.20.1 The answer is that it depends on the circumstances on the Transmission System at the time of the occurrence of the unpredicted shutdown. For example if the market is long and there is a good availability of flexible plant then occurrences of HWSS can be managed using other generation on the system. This management becomes more expensive when the market is short and there is a shortage of flexible plant so high cost plant (usually Open Cycle Gas turbines) has to be used at short notice. Not only are these plants more expensive but they are also more polluting and are less efficient than closed cycle gas turbines. If by the use of good quality forecasting and successful planning the use of short notice plant can be avoided then it is beneficial from a cost, security, environmental and efficiency point of view.

4.21 Appropriate implementation timescale

4.21.1 It was agreed that this Workgroup would report back to the July 2013 GCRP. The timescales for any recommendations are discussed in Section 5 below.

4.22 Other industry developments with respect to wind farms in information provision and operation

4.22.1 Currently available information on HWSS is discussed elsewhere in this document.

4.22.2 The possibility of future turbines operating at higher wind speeds was discussed. Some manufacturers have developed and some are developing systems to offer a more controlled shutdown across a wind farm, or to allow wind turbines to decrease their output more gradually at high wind speeds rather than a sudden drop off. These developments may be adopted by future wind farms where they offer a commercial benefit to the wind farm operator, but the Workgroup did not consider there to be any requirement to seek to incentivise the incorporation of these features into new wind farms.

4.23 Relevant international practice and European Code development.

4.23.1 A representative of SONI addressed the Workgroup in September 2012 to share their experiences of HWSS.

4.23.2 There is some international experience to indicate the issues of HWSS. Discussions and examples provided during Workgroup meetings have demonstrated that wind turbines will shut down when exposed to excessive wind speeds. Whilst evidence has been provided to support the shut down of wind farms the time taken for a wind farm to shut down is typically over a period of several minutes. A hypothetical example of this is shown in Figure 4 below.

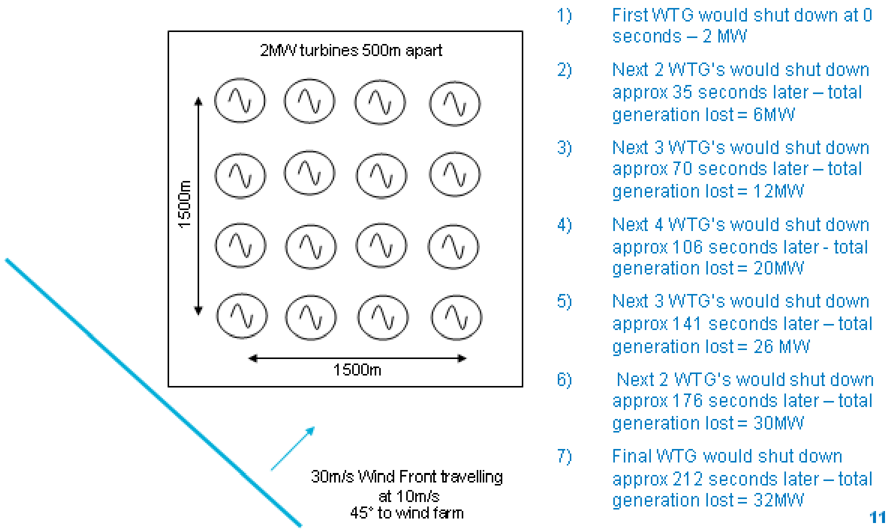

Figure 4 – Theoretical Example of a High Wind Speed Shut Down Event

4.23.3 The experience of HWSS varies from country to country and it also should be noted that the average air densities in general can be lower in continental Europe than in Great Britain. Information from Spain a Portugal indicates that HWSS is not a common event though there have been incidents in the past which have resulted in up to 5 GW of plant being shut down due to high wind speeds.

4.23.4 For example, in January 2005, a hurricane force wind front swept through Denmark resulting in significant reductions in wind power production as a result of HWSS as shown by Figure 5 below however it is believed the turbines concerned are of older fixed speed active / passive stall technology and start shutting down at 20m/s

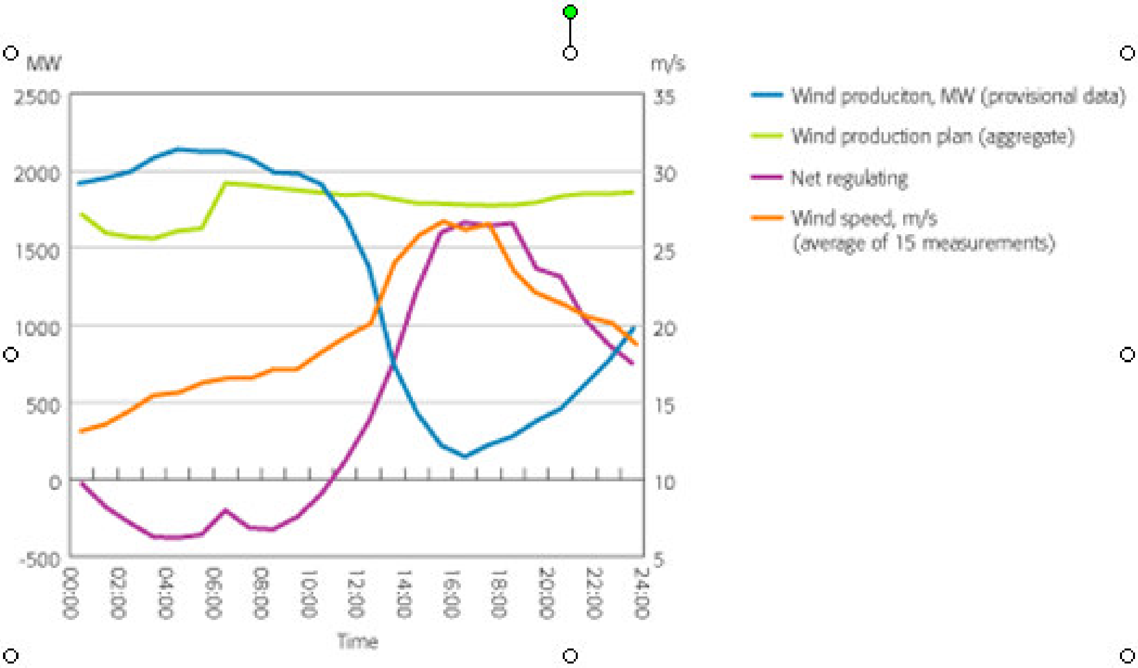

Figure 5 – Wind Power Output Reductions in Denmark during a Hurricane Event in Denmark – January 2005

4.24 European code developments

4.24.1 HWSS is not mentioned in the proposed ENTSO-E RfG, however this would not preclude a HWSS signal from being specified at National level.

5 Workgroup Discussions

5.1 Summary

5.1.1 The Workgroup discussed the consequence of a HWSS Event, and also possible mitigations:

5.2 Do we need a HWSS signal or can we rely on historical data?

5.2.1 After some discussion the consensus of the Workgroup suggested that historical data of shutdown alarms would be relatively easy to supply and that real time signals would be more difficult and more expensive.

5.2.2 A compromise position was suggested that real time signals could be provided from a much smaller subset of wind turbines rather than the complete set provided in the historical data feed.

5.3 Is it possible to use historical data to predict future behaviour, especially with HWSS?

5.3.1 Yes it is possible to use historical data to predict future behaviour. These techniques are already used successfully in areas such as demand forecasting and wind power forecasting more generally. In all cases the more accurate the data and the nearer to real time this data is made available the more accurate the subsequent forecasts.

5.4 To what extent would the provision of a HWSS signal address the System Operator's concerns?

5.4.1 The System Operator's concerns would not be resolved by a signal indicating that a wind turbine is about to shut down as a result of high wind speed. A signal indicating the volume of MW's at risk of suddenly being lost from the System or the number of MW's which could unexpectedly reappear to the system following a fall in the wind speed following a HWSS Event could be useful.

5.4.2 This issue was discussed in detail amongst the Workgroup and it was concluded that better forecasting should provide a satisfactory solution to this issue. A possible solution being that rather than having more operational metering signals provided to the Electricity National Control Centre in real time, data recorded in real time via monitors / data loggers from the wind farm SCADA System and provided to National Grid post event may provide a better input to the forecasting model in being able to predict such Events.

5.4.3 National Grid produces internal forecasts of wind generation, including forecasts of the probability of HWSS. In order to ensure that the system remains secure, there is a conservatism built into the forecast, meaning that National Grid may take actions to manage the risk of HWSS on a number of occasions where HWSS does not occur. This presents an opportunity for cost saving to the industry and consumers by improving the accuracy of the HWSS forecast, and thus reducing the margin of uncertainty built into the forecast. However, the forecast will always be dependant on the accuracy of the wind forecast fed into the model and on the accuracy of modelling the HWSS behaviour of each wind farm.

5.4.4 It was suggested that National Grid should obtain data on HWSS Events under Grid Code OC7 (Operational Liaison) and OC10 (Event Information Supply). OC 7.4.6.2 states

*"In the case of an **Event** on the **System** of a **User** which has had (or may have had) an **Operational Effect** on the **National Electricity Transmission System**, the **User** will notify **NGET** in accordance with **OC7**."*

5.4.5 OC 7.4.6.5 (c) explicitly includes adverse weather as one of the conditions to which OC 7.4.6.2 applies. Appendix 1 to OC 10 lists the data to be reported. This includes the Plant and/or Apparatus directly involved in the Event, the generation (in MW) interrupted and the duration of the interruption.

5.5 Is there a benefit to the industry in National Grid publishing warnings of potential HWSS Events?

5.5.1 Where there is a high probability of HWSS, the Market may choose to partially or wholly manage the risk itself. It was suggested that in order to facilitate any possible market solution, where a high probability of HWSS is forecast, National Grid could publish a System Warning on the BMReports web site advising of a high probability of a HWSS Event, and the volume of generation thought to be at risk.

5.5.2 After discussion it was agreed that given the low frequency of HWSS Events, and the consequences of such an Event at current levels of wind generation, there was insufficient benefit to justify introducing a formal warning process. National Grid is already able to issue free texts warnings on the BMReports website, and could issue a warning if a HWSS Event was forecast.

5.6 Conclusions

5.6.1 The consensus of the Workgroup was that the probability and likely consequence of High Wind Speed Shutdown does not currently constitute a sufficient risk to justify significant expenditure, however this needs to be kept under review as the volume of wind generation increases in the future. In the immediate term it is suggested that National Grid could request HWSS Event data in the post operational phase through OC7 of the Grid Code.

5.6.2 The provision of post-Event data on HWSS Events will enable National Grid to identify the frequency, magnitude and ramp rates of HWSS Events, establish if the probability and likely consequence of HWSS Events increases as more wind generation connects to the system, improve and verify the accuracy of its forecasts, reduce the number of Balancing Actions required and minimise the overall cost of operating the Transmission System.

5.6.3 National Grid is very grateful for the level of collaboration shown in the provision of data from wind farms as part of this Workgroup and would like to thank those Workgroup members that have made data available.

6 Impact and Assessment

6.1.1 This Workgroup does not propose any changes to the Grid Code, instead a change in process to utilise the provisions in OC7 and OC10. The impacts set out below are an assessment of the change in practice.

6.1.2 As there is no Grid Code change, there is no assessment against the objectives.

6.2 Impact on the Grid Code

6.2.1 The Workgroup does not recommend any changes to the Grid Code. The Workgroup's recommendation is that wind farm operators should provide National Grid with data on actual HWSS Events, as detailed in Grid Code OC7 (Operational Liaison) and OC10 (Event Information Supply).

6.3 Impact on National Electricity Transmission System (NETS)

6.3.1 The post-Event HWSS data will allow National Grid to better forecast the probability of HWSS Events, and thus reduce the volume and cost of actions taken to mitigate the risk of such Events.

6.4 Impact on Grid Code Users

6.4.1 Wind farm operators will provide data to National Grid in the event of a HWSS Event under OC7 and OC10. The data presented by Workgroup member's suggests that such Events normally occur less than once a year.

6.5 Impact on Greenhouse Gas emissions

6.5.1 The proposed informal agreements will enable a lower volume of actions to be taken on fossil fuel generation and so will reduce greenhouse gas emissions.

6.6 Impact on core industry documents

6.6.1 The proposed modification does not impact on any core industry documents

6.7 Impact on other industry documents

6.7.1 The proposed modification does not impact on any other industry documents

6.8 Implementation

6.8.1 There are no proposed Grid Code changes.

7 Workgroup Recommendations

7.1.1 Data presented by Workgroup members suggests that HWSS Events occur less than once a year.

7.1.2 At the current time, the volume of generation that would be lost as the result of a HWSS Event is low, however in order to improve its forecasting ability, National Grid will require the submission of HWSS data to be supplied in the post offer period and supplied under the Grid Code OC7 provisions. If the frequency of HWSS Events increases in the future this issue will need to be revisited in the future.

7.1.3 National Grid currently takes actions to mitigate the risk of HWSS Events, based on its forecasting of the probability of such Events. Post Event provision of data to National Grid in the event of a HWSS Event would allow National Grid the opportunity to improve its forecast accuracy, and so reduce the volume and cost of mitigating actions.

7.1.4 The Workgroup recommends:

(a) That no changes should be made to the Grid Code, and that wind farm operators should provide National Grid with HWSS Event information in the post operational phase under OC7 and OC10.

(b) That the Grid Code Review Panel should review the risk and consequences of HWSS Events in two years time, or earlier should further evidence becomes available, and take whatever action it deems appropriate at this time. This review could include an assessment of the efficacy of the data provision arrangements.

nationalgrid

High Wind Speed Shutdown
TERMS OF REFERENCE

Governance

1. The High Wind Speed Shutdown Workgroup was established by the Grid Code Review Panel at the May 2012 GCRP meeting. The issue was original submitted to the January 2012 GCRP where it was agreed that an industry workshop should take place prior to the establishment of a Workgroup.

2. The Workgroup shall formally report to the GCRP.

Membership

3. The Workgroup shall comprise a suitable and appropriate cross-section of experience and expertise from across the industry, which shall include:

Name	Role	Representing
Michael Edgar	Chair	National Grid
Robyn Jenkins	Technical Secretary	National Grid
Graham Stein	National Grid Representative	National Grid
Tony Johnson	National Grid Representative	National Grid
Steve Lam	National Grid Representative	National Grid
Andrew Kensley	National Grid Representative	National Grid
	Industry Representative	Transmission Users
	Industry Representative	Wind Turbine Manufacturers
	Industry Representative	Wind Industry Experts
	Authority Representative	Ofgem
	Observer	

Meeting Administration

4. The frequency of Workgroup meetings shall be defined as necessary by the Workgroup chair to meet the scope and objectives of the work being undertaken at that time.

5. National Grid will provide technical secretary resource to the Workgroup and handle administrative arrangements such as venue, agenda and minutes.

6. The Workgroup will have a dedicated section on the National Grid website to enable information such as minutes, papers and presentations to be available to a wider audience.

Scope

7. The Workgroup shall consider and report on the following:

   (a) Using information currently available, quantify the potential change in risk to the Total System presented by the need to protect wind turbines at high wind speeds by:

      (i) examining the potential volumes of affected generating capacity over time;

(ii) reviewing existing information on the response to high winds over individual windfarms and the GB and Offshore wind fleet as well as relevant international data; and

(iii) comparing high wind shut down power infeed changes to other power infeed changes in the power system including large infeed losses - generator trips, HVDC trips – and large changes in power flows – e.g. interconnector loading changes.

8. In the context of this risk, the Workgroup will:

(a) Review the actions that National Grid may need to take to manage high wind conditions given the risks quantified above;

(b) Review the information that is currently available to wind farm operators on the High Wind Shutdown status of wind turbines and assess the value that provision of this information to National Grid will yield;

(c) Identify additional items of information which could be of benefit and assess the value of providing these to National Grid;

(d) Assess the value of setting out requirements to reduce the impact of High Winds by limiting that rate at which turbines across a windfarm disconnect and reconnect; and

(e) Determine an appropriate implementation timescale for any new requirements.

9. The Workgroup will also:

(a) Take account of other industry developments with respect to wind farms in information provision and operation; and

(b) Take account of relevant international practice and the approach taken in European Code development. The scope of the Workgroup shall not include:

Deliverables

10. The Workgroup will provide updates and a Workgroup Report to the Grid Code Review Panel which will:

- Detail the findings of the Workgroup;
- Draft, prioritise and recommend changes to the Grid Code and associated documents in order to implement the findings of the Workgroup; and
- Highlight any consequential changes which are or may be required,

Timescales

11. It is anticipated that this Workgroup will provide an update to each GCRP meeting and present a Workgroup Report to the January 2013 GCRP meeting.

12. It is anticipated that this Workgroup will develop an implementation plan in line with its assessment of Generation affected by High Wind speeds and its development and connection timescales.

13. If for any reason the Workgroup is in existence for more than one year, there is a responsibility for the Workgroup to produce a yearly update report, including but not limited to; current progress, reasons for any delays, next steps and likely conclusion dates.

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7.2 High Wind Speed Shutdown Event forecasts for January 2013.

7.2.1 The charts below show the wind power forecasts for the last few days of January 2013. This was a particularly windy period and many wind farms experienced high wind which caused turbines at these wind farms to shutdown. The upper chart with the blue curves is the forecast for the active power from the wind. The best (mean) forecast is indicated as a white line on this chart and the uncertainty bands are indicated as blue bands either side of the mean. During periods where wind turbine shutdown is expected the white line includes this possibility and is reduced accordingly. The red line gives an indication of the power output from wind farms assuming they all continued to generate and did not shut down. The charts with the orange and red curves provides a forecast of the expected number of MW lost due to HWSS. The white line showed here indicates that the mean wind speed forecast has exceeded the cut-off speed for some windfarms. The orange and red bands around this indicate the ranges of uncertainty around this mean forecast.

7.2.2 Each of the forecasts shown below were produced at 3am on the day indicated and cover that day and the following 4 days. The vertical lines indicate the midnight point between subsequent days. With each subsequent forecast the data has been completely revised in light of the latest weather forecast available at that time.

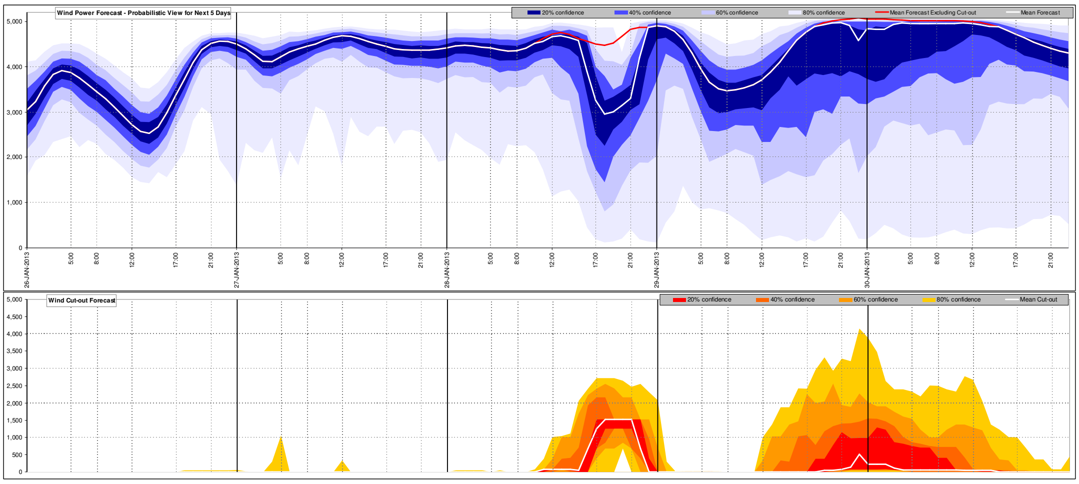


Figure 2A: 26th January 2013

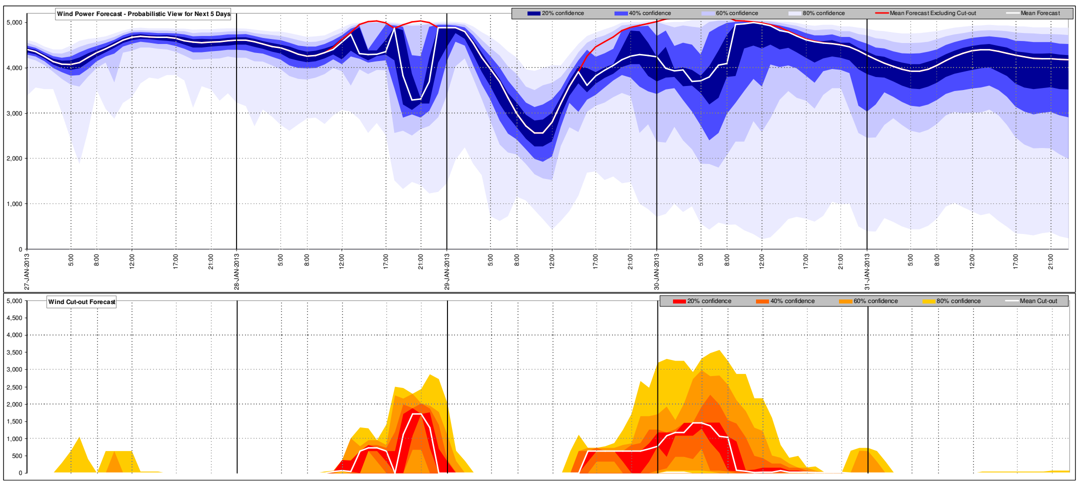


Figure 2B: 27th January 2013

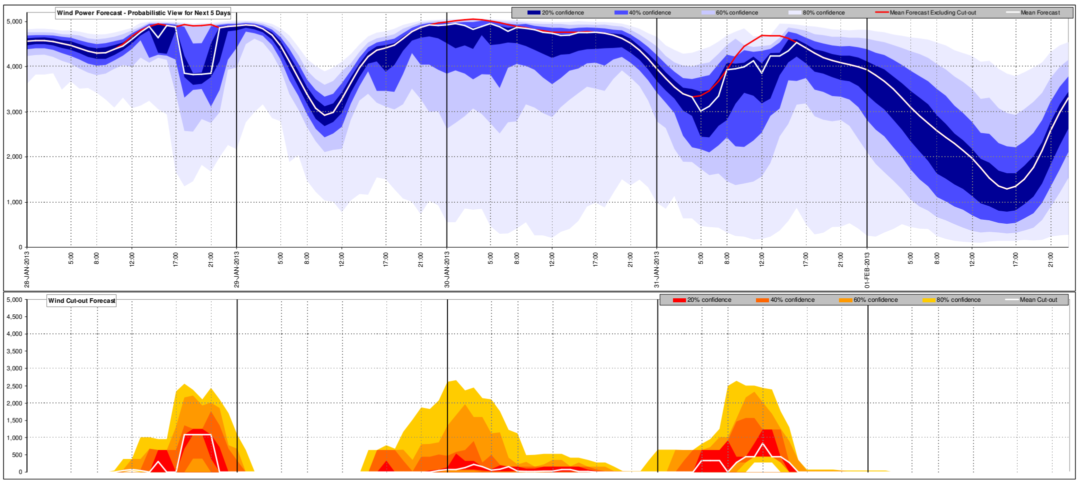


Figure 2C: 28th January 2013

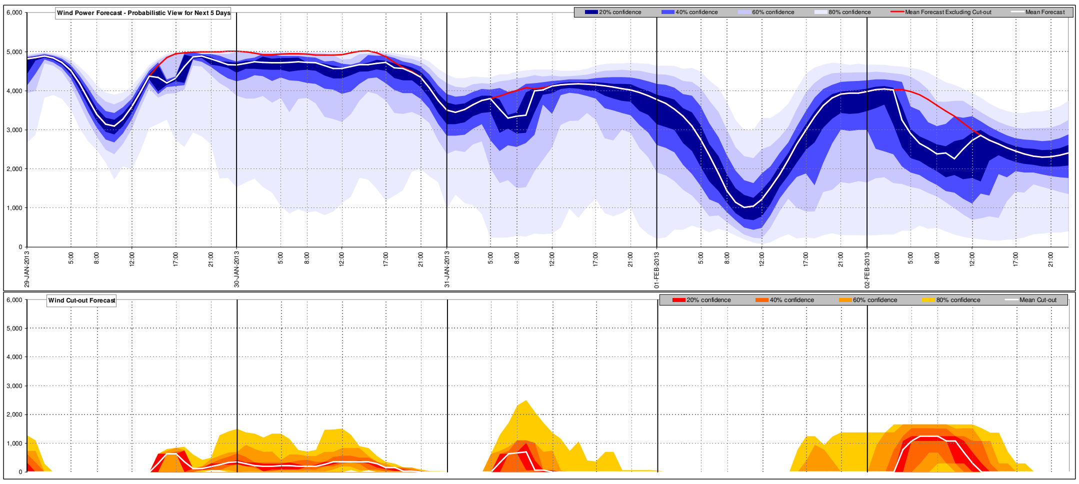


Figure2D: 29th January 2013

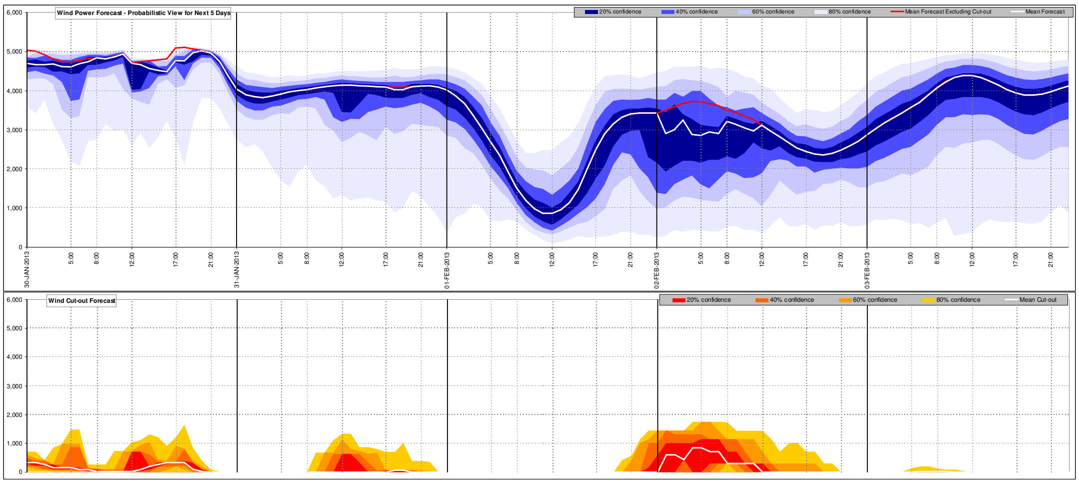
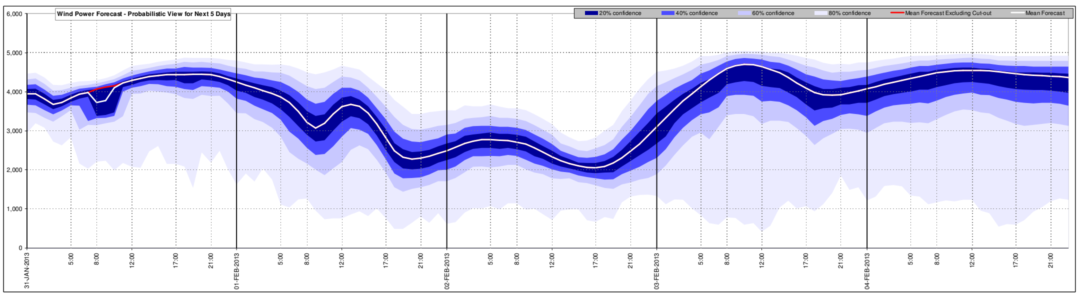


Figure 2E: 30th January 2013



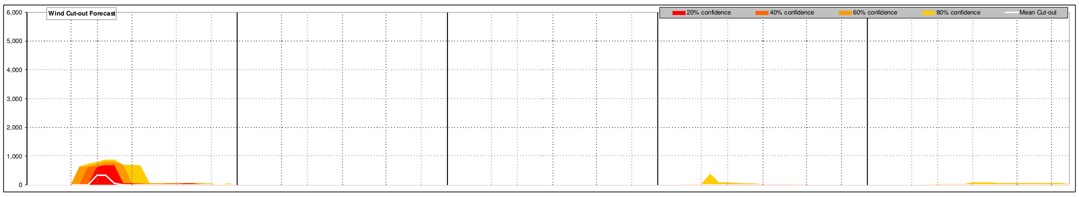


Figure 2F: 31st January 2013

7.2.3 The charts above demonstrate that the wind power forecasting systems available to National Grid provide a warning to the electricity national control room that there is a risk that in future days that MW will be lost from the system due to HWSS. It also shows that this level of risk changes with each forecast update and subtle changes in wind speed can cause large changes in the forecast.

7.2.4 It is the forecasting horizon near to real time (0 to 4 hours ahead) where greater feedback is required to enable the provision of enhanced forecasts which represent the current situation more accurately.

7.3 Research Requirements

7.3.1 National Grid has approached Reading University Meteorology department and is currently sponsoring research to improve capability in the short term prediction of wind power. Two researchers are currently sponsored. One has been looking at general trends in the weather over the past 30 years and the other will be examining more detailed airflows on the scale of a single wind farm using the Large Eddy Simulation method. It is hoped that by the combined efforts of these researchers and the data that has been provided from Grid Code Workgroup members an increased forecasting capability will be developed. This will enhance predictability of wind power generally as well as those times when high winds have been forecasted.