Technical Appendix 1: How the system will work

In the study of variability below, monitoring data from the output of the current wind resource for the period 23 October 2008 to 13 January 2009 was used and scaled up to 33GW, which is the government's Round 3 target. This is how the results would read under this scenario.

Example 1: wind turbine ramp up
Starting on the 11 December 2009, 9.30am, the power output from wind turbines was 198MW; after 31.5 hours the output ramped up to 24,868MW, an average rate of change of 392MW per half hour, the peak half hour change being 2,310MW. On nine occasions the increase in production was in excess of 1,000MW. The steepest rise of 12,139MW occurred starting 8 hours before the peak and lasted 5 hours at an average of 1,214MW per half hour.

When the output of wind farms dropped below demand, there was a need to reduce demand. Smart immersion heaters were turned off, and other demand side options delayed appliances from turning on. The sale of electricity via interconnects switched to the purchase of electricity, and hydro electricity and pumped storage were brought on line.

Example 2: wind turbine ramp down
The power output then took 20.5 hours to fall back to 198MW on 13 December 2009, 9.30am. There was an average rate of change of -602MW per half hour, the peak half hour change being -3,512MW. On eight occasions the loss in production was in excess of 1,000MW. The steepest fall -14,826MW started 3.5 hours after the peak and took 4.5 hours at an average of -1,647MW per half hour.

In addition to this scaled up monitoring data scenario it is important to factor in the following: during periods of low wind speed when there is a risk of wind turbines consuming more electricity than they produce, only a subset of turbines in a farm should be allowed to spin in readiness of to respond to the available wind resource. The rest should be locked down until the wind speed guarantees production of stable electricity for a manageable period. This approach allows for both the manageable power up of a wind farm and the controlled reduction in energy production from other sources.

In order to keep the network stable when the output of national wind farms is undergoing its maximum rate of change, any extra electricity needs to be channelled into recharging pump storage systems, while about one third of the rate of change should be exported via interconnects to France, The Netherlands and elsewhere.

New interconnects should be built with Norway and Sweden, which produce 99% and 50% of their electricity respectively from hydro. These may be smaller countries than the UK, but together their total electricity production is on a similar scale to that of the UK. It is worth noting that from these two countries it is also possible to reach the electricity markets of Poland, Denmark, Finland and Northern Germany, and there are plans to build a HVDC ring to link together the states on the Baltic.

When the output of electricity is greater than the demand and capacity for storage, there are a number of options available: if demand-side management has been implemented, instructions can be sent out over the grid to those devices with a smart meter, immersion heaters could be turned on early, electric cars charged and electricity sold to neighbouring countries. Plus, any turbines running close to the cut out speed could be stopped in a controlled manner, removing the unpredictability of automatic shut down.

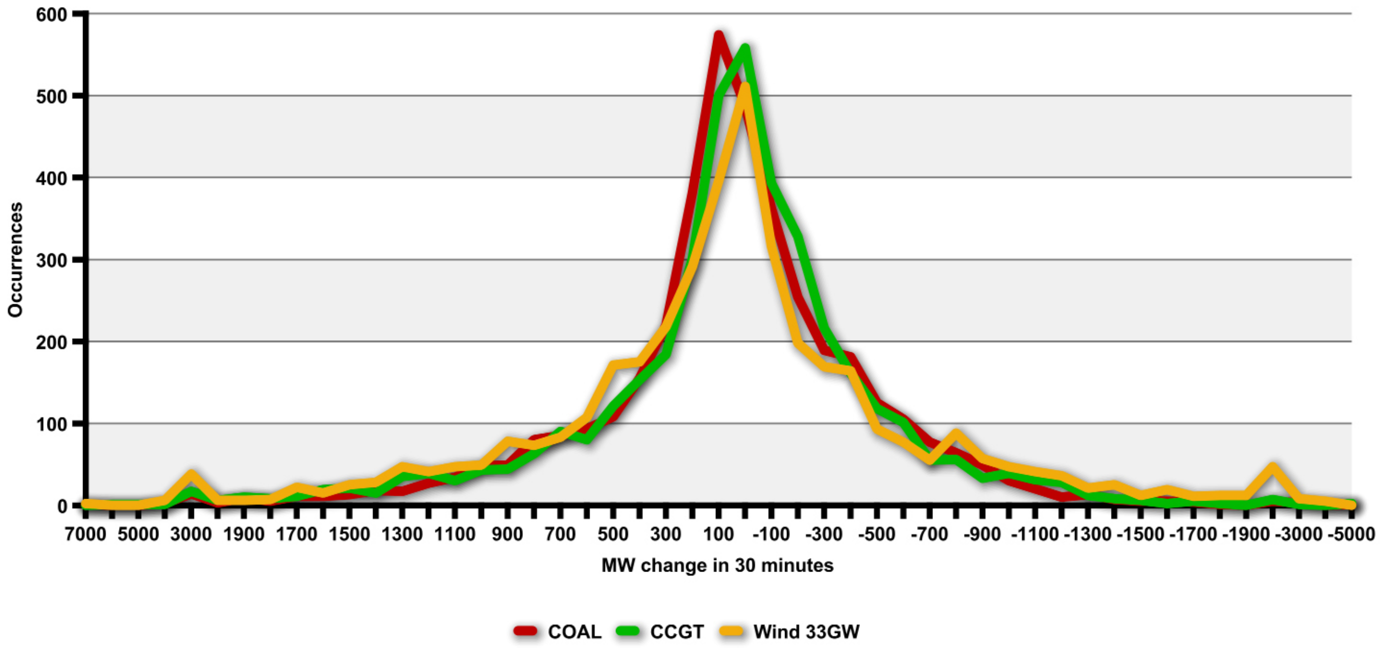
The table below shows the frequency distribution for two existing power stations with their current 1.4GW of wind power output scaled up to 33GW in half-hour slots. (Please be aware of the fact that the Microsoft frequency function works differently with negative number than might be expected.)

Data	**Bin**	**Frequency**	**Bin range**
19	19	3	11to 19
12	10	2	6 to 10
11	5	5	1 to 5
10	0	0	0
9	-1	4	-1 to -4
5	-5	2	-5 to -9
4	-10	3	-10 to -18
3	-19	1	-19 to -inf.
2			
1			
-1			
-3			
-4			
-5			
-9			
-10			
-11			
-12			
-19			

Microsoft frequency function and negative bin numbers
With positive numbers the function works up to the number in the bin. With negative numbers the function starts with the bin values and then goes down in value to the last number before the next lowest bin

This data is shown in the following graph and indicates that any potential shock to the electricity grid from Round 3 quantity of wind would be no greater than those currently experienced from conventional sources.

As can be seen from the graph, the National Grid have similar rates of change to manage from coal and gas power stations as they might have to manage with the introduction of wind power at Round 3 quantities.



Note: The vertical axis indicates the number of events of the magnitude shown on the horizontal axis.