Neutral Citation Number: [2017] EWCA Civ 5

Case No: A3/2015/3243

IN THE COURT OF APPEAL (CIVIL DIVISION)
ON APPEAL FROM THE HIGH COURT OF JUSTICE
CHANCERY DIVISION (PATENTS COURT)
THE HON MR JUSTICE BIRSS
[2015] EWHC 2114 (Pat)

Royal Courts of Justice
Strand, London, WC2A 2LL

Date: 19/01/2017

Before:

LORD JUSTICE LONGMORE
LORD JUSTICE KITCHIN
and
LORD JUSTICE FLOYD

- -

Between:

WOBBEN PROPERTIES GmbH	**Claimant/ Appellant**
- and -	
(1) SIEMENS PUBLIC LTD COMPANY **(2) SIEMENS WIND POWER A/S** **(3) SIEMENS AG** **(4) DONG ENERGY A/S** **(5) WESTERMOST ROUGH LTD** **(6) DONG ENERGY GUNFLEET SANDS DEMO (UK) LTD** **(7) A2SEA A/S** **(8) A2SEA LTD**	**Defendants/ Respondents**

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Mr Michael Silverleaf QC and Mr Adam Gamsa (instructed by Rouse Legal) for the Appellant/Claimant
Dr Justin Turner QC and Mr James Whyte (instructed by Bristows LLP) for the Defendants/Respondents

Hearing dates : 16/17 November 2016

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Judgment Approved

Lord Justice Kitchin:

Introduction

1. The claimant ("Wobben") is the proprietor of EP (UK) 0 847 496 entitled "Method of Operating a Wind Power Station". The patent relates to a method of operating pitch-controlled wind turbines in high wind speeds. It claims priority from a German filing on 1 September 1995 and was granted on 9 August 2000.

2. In these proceedings Wobben claimed that the defendants (collectively "Siemens") had infringed the patent by installing wind turbines at off-shore sites at the London Array, Westermost Rough and Gunfleet Sands. Siemens disputed infringement and also contended that the patent was invalid for lack of novelty, obviousness and insufficiency. During the course of the proceedings Wobben made an unconditional application to amend the patent. In the end, this application was not opposed by Siemens.

3. The action came on for trial before Birss J in June and July 2015. It lasted for six days. The judge heard evidence from three experts. Professor Leith gave evidence for Wobben on the issues of infringement and validity. He is a Professor in the School of Computer Science and Statistics at Trinity College Dublin. At the priority date, he was working in the Industrial Control Unit at the University of Strathclyde, one of the leading research groups in the UK on wind turbine control. Two experts gave evidence for Siemens. Mr Butterfield dealt with validity. He has long experience of wind turbine manufacturing and by 1994 was the chief engineer of the National Wind Technology Center of the National Renewable Energy Laboratory ("NREL"), a US wind technology research and development laboratory. Dr Santos dealt with infringement. He has a PhD in Aerospace Sciences and from 1997 to 2004 worked at NREL on the certification and design evaluation of wind turbines. Professor Leith and Mr Butterfield gave their evidence fairly and each of them was experienced and knowledgeable. Dr Santos also had considerable experience. He descended into argument a number of times but, so the judge held, this was not to a degree which justified discounting his evidence altogether.

4. The judge handed down his judgment on 20 July 2015 ([2015] EWHC 2114 (Pat)). He found the patent invalid for obviousness in light of an article by Dr Ervin Bossanyi entitled "*Probabilities of sudden drop in power from a wind turbine cluster*" which was published in 1982 ("Bossanyi"). He also held that, if the patent were valid, it would not have been infringed.

5. Wobben now appeals against those findings with permission granted by the judge himself. It contends that the judge wrongly directed himself as to the legal test for obviousness and made a series of fundamental errors in assessing the evidence of the expert witnesses. It also argues that the judge erred in assessing infringement and made findings which had no basis in the evidence. Siemens responds that the judge's findings are properly supported by the evidence and are correct, essentially for the reasons that he gave.

6. I will deal with obviousness and infringement in turn. But first I must summarise the relevant aspects of the common general knowledge and the teaching of the patent.

Technical background and the common general knowledge

7. The patent is directed to a general wind turbine engineer, referred to by Mr Butterfield as a systems engineer. This engineer would obtain input from a control engineer where necessary. Both of these engineers would have similar backgrounds and be interested in the control aspects of a turbine. The following description of the common general knowledge of such a systems engineer, the notional person skilled in the art, is drawn in large part and with gratitude from the decision of the judge and from those parts of the reports of the experts about which there was no dispute.

Wind

8. The power available from the wind is proportional to the cube of the wind speed. The speed of wind varies over time and from location to location. Average wind speeds of about 10 m/s are common but wind speeds above 20 m/s become increasingly rare. Superimposed upon these average wind speeds are short-term fluctuations associated with turbulence and gusts. The size and frequency of these fluctuations tend to increase with an increase in mean wind speed.

Generators

9. Wind turbines convert the kinetic energy of the wind into electrical energy. This is achieved by a generator. A generator is designed to have a maximum electrical power output, the rated power, at which it can be operated continuously. Exceeding this limit can lead to the generator overheating or suffering other damage. By 1995 commercial wind turbines generally used synchronous generators or induction generators. They both have an input shaft and when torque is applied to that shaft, the turning motion produces electrical output from the generator. It also induces a reaction torque on the shaft. When a synchronous generator is connected directly to the electricity grid, the reaction torque is such that the rotation speed of the generator is locked to a fixed multiple of the grid frequency. When an induction generator is connected directly to the electricity grid, the generator speed is not locked precisely to the grid frequency but instead will vary or slip by, for example, 2 to 5% around a fixed multiple of the grid frequency.

Turbine types – constant and variable speed

10. At the priority date, the majority of commercial turbines contained synchronous or induction generators which, when the turbine was generating power, were connected directly to the grid. Once there is sufficient wind to make generating electricity worthwhile, the turbine is connected to the grid and the rotor rotates at its constant or near constant rate determined by the grid. As the wind speed increases, the power generated by the turbine increases (power = torque x speed) until rated power is reached. If the wind speed increases still further, the power generated by the turbine is held approximately constant using aerodynamic control methods such as pitching the blades into the wind (feathering), pitching the blades to induce a stall or designing the blades so that they stall automatically. Yaw control can also be used to turn the turbine out of the wind.

11. Variable speed turbines were also in commercial use although relatively few manufacturers were producing them. Variable speed operation requires some form of

power electronics to decouple the generator speed from the grid frequency. The power electronics normally convert the electricity from an alternating current produced by the generator to a direct current and then back to an alternating current at a fixed frequency suitable for the grid. The power electronics also allow the reaction torque of the generator to be varied. Variable speed turbines which have the ability to vary the pitch of the blades are called variable speed variable pitch (VSVP) turbines. This combination of features, that is to say the ability to vary both the torque and the blade pitch, was referred to by the judge as the "two knobs to turn" feature. Wobben describes VSVP machines as being "old and new" at the priority date. The idea was old but commercialisation had been held back by the high cost of power electronics. By 1995, the priority date of the patent, the falling price of power electronics had made VSVPs commercially feasible and the industry was focused upon them.

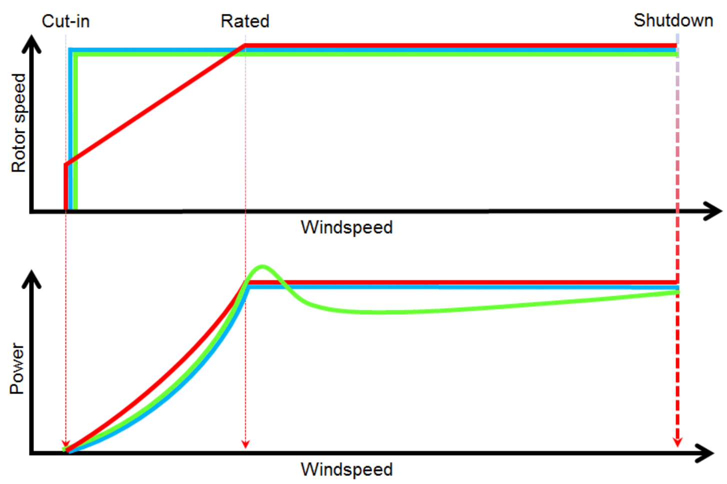
12. As Professor Leith explained, below rated wind speed, VSVP operation allows the rotor to operate at different speeds, depending upon the wind speed. In slower wind speeds, the reaction torque can be adjusted so that the rotor rotates at a slower speed. In higher wind speeds, the torque can be adjusted to allow the rotor to rotate more quickly. Adjusting the rotation speed to match the wind speed in this way maximises the power generation efficiency of the turbine. VSVP operation can therefore be used to increase the efficiency of the turbine in the operating region below rated wind speed.

13. When the wind speed increases above the rated wind speed, the turbine is operated at approximately constant rotational speed. The reaction torque and the output power of the generator are held constant, and the rate of rotation is held at approximately the rated rotor speed by continuously adjusting the pitch angle.

14. These different modes of operation are the foundation for the practical advantages of the VSVP turbine, as I shall now explain.

The advantages of VSVP operation

15. VSVP turbines have two advantages over constant speed turbines and these are conveniently described by reference to this diagram which must be seen in in colour:

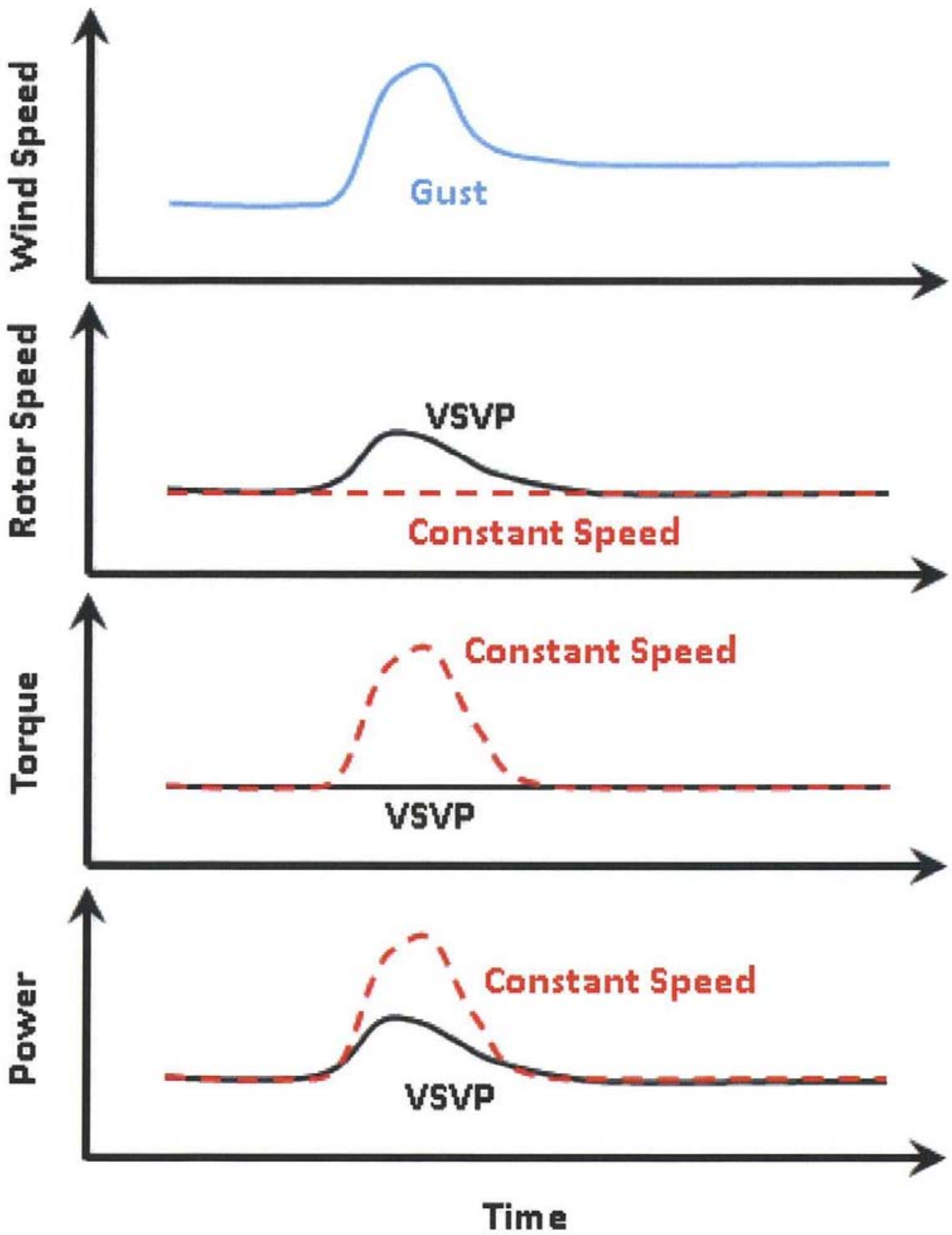


The red lines represent the operation of a VSVP turbine, the green lines a constant speed, stall regulated, turbine and the blue lines a constant speed, variable pitch, turbine.

16. The first advantage arises in relation to operation below the rated rotor speed and is a matter to which I have referred. This region of operation was referred to at the trial as region II. The judge described how the benefit arises in these terms with which neither side has taken issue:

> "44. … The first advantage relates to what is known as the C_P–λ curve. This curve relates the ratio of the speed of the tip of the rotor blade relative to wind speed (λ) to the power coefficient of a rotor (C_P). The power coefficient C_P relates rotor power output to the dynamic power of the wind. For a given pitch angle there is an optimum tip speed ratio at which maximum power is extracted. When the wind speed is below rated speed a VSVP turbine can be adjusted to track the optimum position the C_P–λ curve. That is why the red line is above the green and blue lines in region II in the diagram above."

17. The second advantage arises in relation to operation once the rated rotor speed has been reached. This region of operation was referred to at the trial as region III. As Mr Butterfield explained, in this region, the VSVP concept reduces the effect of aerodynamic torque fluctuations. In a VSVP machine, when a gust is encountered, and there is a corresponding increase in the aerodynamic torque, the rotor is allowed to accelerate instantaneously, driven by the torque imbalance. In this way the torque imbalance contributes to the acceleration of the rotor rather than being transmitted through the drivetrain. The ability of the rotor to store energy in this way, like a flywheel, protects the drivetrain from the transient additional drivetrain torque. By contrast, with a fixed speed rotor, when a gust is encountered, the rotor speed remains fixed and a significant increase in drivetrain torque is therefore experienced until the control system reacts and adjusts the pitch of the blades. Mr Butterfield illustrated this difference in his figure 19 which also needs to be seen in colour:



Forces on a rotating turbine blade

18. The skilled person would have an understanding of the various aerodynamic forces operating on a rotating turbine blade and on the turbine itself. The judge summarised that understanding in terms upon which I cannot improve:

> "67 … The forces derive from considering the velocity of the wind itself and peripheral velocity due to the spinning of the rotor. Generally the wind velocity is perpendicular to the rotor. The peripheral velocity will be in the plane of rotation of the rotor. The velocity of the incident stream over the blade aerofoil is the vector sum of the wind velocity and peripheral velocity. The lift force generated by the air flow over the blade

> is itself a vector. It has a component in the plane of rotation which drives the rotation and does work generating power and another component (thrust) which pushes against the tower. For a given pitch angle of the blade, as the speed of rotation changes, the forces experienced by the blade change accordingly. That is because the change in peripheral velocity alters the magnitude and direction of the incident stream velocity due to the vector sum and thereby alters the aerodynamics across the blade."

Loads and fatigue

19. The loads on a wind turbine have both a steady component, referred to as a static load, resulting from the mean wind speed, and a dynamic component resulting from turbulence or gusts in the wind. The turbulence itself has two components: a natural component but also a component resulting from the blades passing repeatedly through their swept area, within which the wind speed may vary from place to place. As the judge explained, different parts of the turbine can be exposed to different and changing loads and operation in high winds requires an increasingly robust structure.

20. Fatigue is a type of damage to structural materials that results from the application of varying loads, such as dynamic thrust loading, and is related to the mean load and the amplitude and number of loading cycles. Not surprisingly, turbulence, especially at high wind speeds, is a particular problem.

21. It follows from all of the above that any engineer designing a wind turbine must have careful regard to the wind conditions in which the turbine will be operating and the turbulence to which it may be exposed. The designer has to balance the benefit of operating at high, but increasingly rare, wind conditions with the cost associated with making the wind turbine robust enough to cope with the increased loads and fatigue it may experience. As the judge explained, a point is reached at which the balance often favours shutting the turbine down and not exposing it to the loads associated with the higher wind conditions.

Shut down

22. As I have mentioned, VSVP turbines operating in region III, that is to say above rated wind speed, were generally run with constant rated power and constant rated rotor speed. However, turbines were usually shut down if the wind speed reached 25 m/s. Wind speeds of 25 m/s are not common and the cost of building a machine robust enough to cope with the extra loads and fatigue associated with operation at such speeds was considered not worth the extra power that might be generated. Fatigue caused by dynamic loading was a particular concern.

23. The judge went on to hold that there was no prejudice against operating VSVP wind turbines at speeds in excess of 25 m/s. Nevertheless, the skilled person would not have been prompted by his or her common general knowledge alone to think about operating a VSVP turbine above this wind speed because the norm was to shut it down. Nor would the common general knowledge alone have prompted the skilled person to think about a different way of operating a VSVP turbine in high winds. However, the skilled person who was prompted to consider operating above the shut

down wind speed would have in mind the aerodynamic forces to which the turbine blades would be subjected and would be interested in the effects of loading and fatigue upon how the turbine would be operated. This finding is of some importance in considering the issue of obviousness, as I shall explain.

The patent

24. The patent relates to a method of operating a pitch-controlled wind turbine. As both parties have accepted, it has a particular relevance to VSVP turbines. I need only refer to a limited number of passages to address the issues arising on this appeal.

25. The problem to which the patent is directed is explained at [0009] as being the sharp power gradients experienced when VSVP turbines are shut down once a maximum wind velocity is reached and later restart when the wind velocity drops:

> "Particularly in the case of wind parks, such a shutdown, where all the wind turbines of the wind park shut down virtually simultaneously when shutdown velocity is reached, and the restarting after such a shutdown with a decreasing wind, leads to sharp power gradients, which are reflected in a sudden change in voltage in the electrical network to which these wind turbine are connected."

26. The object of the invention is described at [0011]:

> "The object on which the invention is based is to increase the yield of a wind turbine and nevertheless limit the load on the wind turbine at higher wind velocities."

27. The background to the invention is elaborated at [0013]. It is said that the dynamic pressure loading the rotor blade, as well as the force acting at the blade profile and thus loading the rotor blade, depends in each case on the peripheral velocity and thus on the operating speed of the rotor. Accordingly:

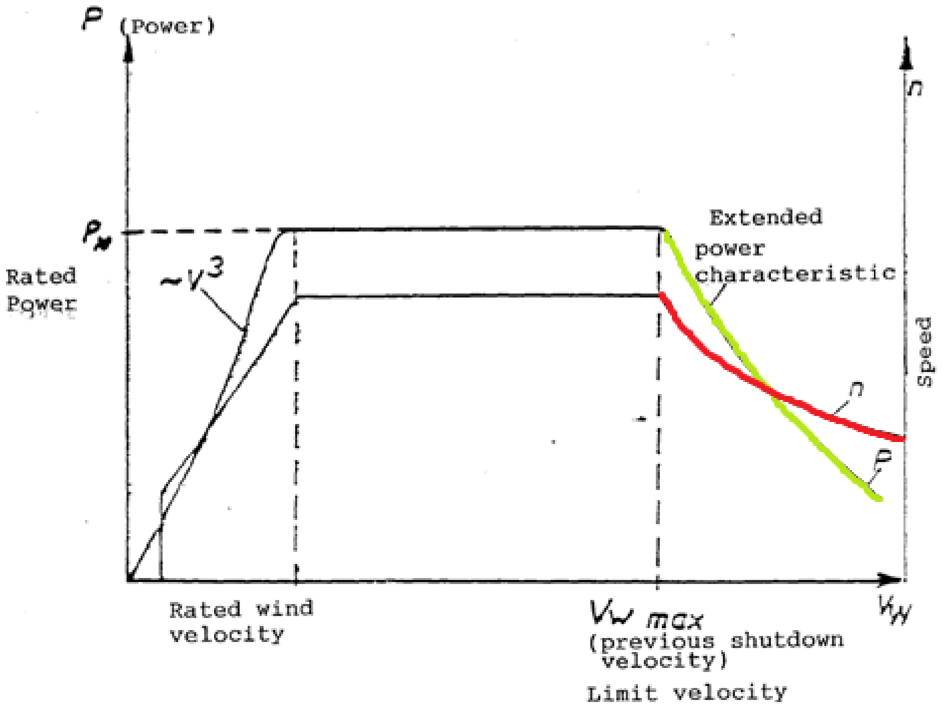
> "To limit the load on the rotor of the wind turbine, therefore, when the wind velocity v_W rises or when the incident-stream direction is unfavourable (depending on which parameter is taken as the quantity to be measured), which could in each case lead to an unfavourable increase in the resultant incident-stream velocity v, it is possible to counteract an increase in the load by reducing the speed, i.e. the peripheral velocity, of the rotor."

28. The invention itself is introduced at [0014] and is, in summary, to reduce the speed of the rotor as soon as the incident stream velocity increases above the value of the customary shut down velocity, and in this way to allow the turbine to continue to operate and so extend its power yield and network compatibility:

> "In contrast to what has been provided previously, therefore, according to the invention the wind turbine advantageously will not be completely shut down when a limit velocity is reached, and this limit velocity is thus not defined as the shutdown

> velocity, but rather the wind turbine is merely compulsorily reduced in its operating speed as soon as the incident-stream velocity v increases above the value of the limit velocity. The wind turbine can thus be continued to be operated above the customary "shutdown velocity", thereby extending its power characteristic at greater wind velocities and improving the power yield and the network compatibility of the wind turbine. In particular, it is possible, through the compulsory operating-speed reduction in the case of pitch-controlled wind turbines, to limit the loads in a favourable manner by means of the invention. Excessively strong, changing loads on the rotor blades and hence excessively unbalanced, pulsating loads on the entire turbine, which increase with rising wind velocity, are avoided by means of the invention."

29. The operation of the invention is shown diagrammatically in Figure 1 which, with colour added, looks like this:



30. As the judge explained, in region III, rotor speed and power remain constant, as in conventional operation. The difference from the conventional approach comes once the limit velocity is reached. Instead of shutting down, operation is continued in what is described as the "extended power characteristic" with both power and rotor speed being continuously reduced as the wind speed increases.

31. The invention is encapsulated in the claims of the patent as proposed to be amended. Claims 1 and 4 were said to be independently valid but in the end nothing turned on the difference between them. So I need only refer to claim 1 which reads:

> "1. Method of operating a wind turbine for the production of electricity in an electrical network with pitch control, in which the power of the wind turbine as well the operating speed of the rotor is continuously reduced when a wind velocity is reached which is in danger of overloading the wind turbine, in dependence on the rise in the wind velocity."

32. The judge made various findings as to the proper meaning of this claim. His key findings are these. First, the claim covers any suitable measure of wind speed. Secondly, the claim calls for a dependency between the reduction in rotor speed and the rise in wind speed. To satisfy the claim, there must be a causal relationship between the rotor speed and the wind speed. So also, there must be a causal relationship between the power of the turbine and the wind speed. Finally, the claim covers a method in which two different approaches to determining wind speed are used, one to control power and the other to control the rotor speed.

Inventive step and obviousness

33. Bossanyi is, as Wobben asserts, a publication of a theoretical study investigating the frequency of sudden decreases or increases in the power output of wind turbine clusters and control strategies that might mitigate their impact on the electricity grid. In 1982, the date of its publication, virtually all wind turbines, including the Mod-2 turbines used in the study, were fixed speed turbines. Dr Ervin Bossanyi, the author of the paper, was a leading figure in the wind power industry.

The disclosure of Bossanyi

34. Bossanyi says in its introduction that, when the wind speed is near to the furling (shut down) speed, when individual windmills may be switching between full and zero power quite frequently, the probability of a large change (ramp) in total cluster output is quite small. More serious, however, is the case where an increase in wind speed from below the shut down speed to above it passes through the cluster, causing successive rows of turbines to shut down so that the whole cluster output ramps down from full power to zero power in a fairly short time. The reverse process, giving an upward ramp, is also possible, and would be of interest to grid system planners but its consequences are probably less severe. Accordingly, Bossanyi describes attempts to quantify these effects by estimating the frequency of an event which might cause them and then modelling how different control strategies might mitigate their consequences.

35. All of this is foreshadowed in the "Summary" at the beginning of the paper, which reads in material part:

> "With one simple strategy for furling and unfurling in high wind speeds, the number of occasions when the full output of a 10 km long cluster drops to zero within a few minutes is small. However, this entails a fairly large number of furls for each windmill. Yet the use of a strategy designed to reduce the frequency of furling of an individual windmill actually has an adverse effect on the output of the cluster, increasing the number and severity of large power ramps. Thus care is needed

> in selecting the control strategy, and it may be advantageous to use a single centralised control system to control the furling and unfurling of all the machines in the cluster. However, the use of a windmill whose output can be reduced gradually to zero as the wind speed increases is also investigated, and this reduces severe ramping of the cluster output as well as being advantageous to the individual windmill."

36. Section 2 of Bossanyi describes attempts to assess the probabilities of large excursions of cluster output due to turbulence. It is assumed that the whole cluster is experiencing mean wind speed near to the shut down speed and that fluctuations in wind speed due to turbulence at different locations in the array are not correlated, that is to say, they are statistically independent. It is said that in these circumstances there is only a small probability of large excursions in cluster power output.

37. Section 3 of Bossanyi describes an investigation into the situation in which the changes in wind speed are correlated due, for example, to a weather front passing over the cluster. As Professor Leith explained, in this case it is clearly more likely that the wind turbines will together experience an increase in wind speed such that they shut down. The paper attempts to quantify this risk and its impact upon cluster output.

38. For this purpose Dr Bossanyi used one-minute-average measurements of wind speed to estimate the behaviour of the cluster. He did not have any data showing how wind speed varied with time across different locations within a cluster of the size he had in mind. Accordingly, he used one month's worth of one-minute-average wind speed data gathered at one location in Valley in Anglesey and supplied to him by the Meteorological Office. He then proceeded to carry out his modelling exercise. In doing so, he had to make a number of assumptions, as the paper explains.

39. Table 1 of the paper shows the results for the base case, with a cluster size of 10 km and a shut down speed of 20.1 m/s. It was found that the worst downward power ramps were two cases in which the power dropped by between 0.7 and 0.8 of cluster rating in a time of between 6 and 10 minutes. It is said there were not enough data to give a reliable figure for the number of these ramps to be expected in a whole year, however. Tables 2 and 3 gave corresponding results for cluster sizes of 5 km and 25 km respectively. The 5 km cluster produced more severe ramps, including three cases where the power dropped by 0.9 to 1.0 of rated power in 5 minutes or less. In the case of the 25 km cluster the situation was much better, with no downward ramps of more than 0.6 of rated power in 20 minutes.

40. Bossanyi then considers the effect of adjusting the shut down speed to 17.2 m/s but otherwise using the same conditions as those for table 1. The results are shown in table 4. There was a considerable increase in the number of shut downs of each turbine and an increase in the number (though not the severity) of the power ramps.

41. The remaining tables show the effect of changing the wind turbine control strategy. It is explained that a useful scheme for reducing the number of shut downs of a single turbine is to introduce some hysteresis into the system, that is to say to adjust the control system so that a turbine which has shut down is not restarted until the wind speed has dropped by a particular fraction of the shut down speed. It was found that this significantly reduced the number of shut downs of any individual windmill but

led to a considerable increase in both the number and the severity of ramps in the power output from the cluster. It also caused some reduction in the annual energy yield from the field.

42. Bossanyi turns next to another control strategy which is of particular importance to this case. It is said that with some wind turbine designs it should be possible to arrange for a gradual shut down rather than a sharp cut-off at the shut down speed. It continues that, with a variable pitch horizontal axis turbine, this could be done by pitching the blades to reduce the angle of attack progressively towards zero as the wind speed increases above the original shut down speed, so reducing the power output and the aerodynamic forces on the blades.

43. This is said to have a number of advantages for the individual turbine: the shut down speed is increased at little extra cost, so reducing the frequency of shut downs while slightly increasing the annual energy yield. In addition, rather than switching off from full power the machine is now finally shut down when the power output is near zero, so that the shock to the turbine's various electrical and mechanical components is likely to be less.

44. Bossanyi continues that there should also be a benefit in terms of power ramps in the output of a large cluster. Two such gradual shut down strategies were tried, as shown by lines (a) and (b) in figure 3 below:

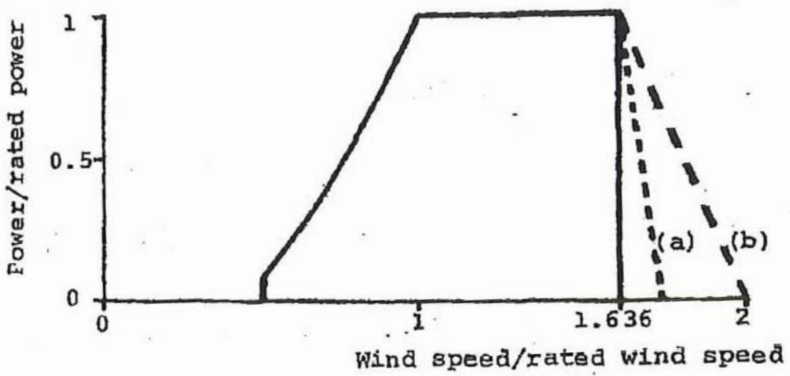


Fig. 3. Normalised Wind Turbine Characteristics

45. Power is assumed to decrease linearly from the original shut down speed of 1.636 times rated speed. Power reaches zero at 1.75 times rated speed (in the case of line (a)) or at twice rated speed (in the case of line (b)). The results for a 10 km cluster and an original shut down speed of 17.2 m/s are shown in table 10 (for line (a)) and in table 11 (for line (b)). These results are then compared with those in table 4, which models the results of operating a cluster of the same size under the same conditions save that a sharp cut-off is imposed at 17.2 m/s. It is also observed that results comparable to those in table 1, with an original shut down speed of 20.1 m/s, are not given, owing to the lack of sufficiently high wind speeds in the data sample.

46. The conclusion of this particular modelling exercise is stated at [0030]:

> "Table 10, using line (a) of Fig. 3, gives only a very slight improvement over the sharp cut-off case, although the number of furls of each windmill is of course reduced. However, line (b) of figure 3 (Table 11) gives quite a substantial improvement. Thus it seems that the feasibility of such a control strategy is worth investigating."

47. There follow the overall conclusions from the whole study, including, at [0034] to [0035]:

> "Changing the windmill control strategy to reduce the number of furls per machine may actually increase both the number and the severity of power ramps in the output of the cluster, so considerable care may be needed in choosing the right strategy. With a number of anemometers throughout the cluster there may be a case for a centralised control system to decide when to stop and start each windmill, taking into account the progress of gusts and fronts as they move across the cluster.
>
> However if the wind turbine can be controlled in such a way as to bring the power output gradually down to zero at high wind speeds then the situation is improved both for the individual windmill and also for the cluster by reducing severe power ramping in cluster output."

The judge's assessment – an outline

48. Birss J identified the difference between Bossanyi and claim 1 as being that claim 1 calls for a reduction in both the power of the turbine and the operating speed of the rotor in high winds whereas Bossanyi only refers to a reduction in power. The critical question was whether this difference involved an inventive step.

49. Siemens' case was relatively straightforward and was founded upon the evidence of Mr Butterfield. It contended that the skilled person reading Bossanyi in 1995 would be interested in its reference to the impact on the grid of large reductions in power from wind farms resulting from, say, a weather front passing through the turbine array. At this time the industry was focused on VSVP turbines and so it would be obvious to consider putting the power ramp proposal of Bossanyi into practice using such turbines. In designing a VSVP turbine, loading and fatigue would be regarded as serious concerns, particularly if the turbine might be run at speeds above the normal shut down speed. So, in applying Bossanyi to a VSVP machine, it would have been obvious to at least consider reducing rotor speed as well as power because this would reduce loads and fatigue.

50. Wobben contended the opposite and relied upon the evidence of Professor Leith. It argued that the skilled person would have had no particular interest in Bossanyi in 1995 and would not have been concerned with issues of cluster power output because wind energy was not being generated on a large enough scale for shut down to affect the power grid in any significant way. Secondly, Bossanyi describes the use of the Mod-2 constant speed turbine and shut down speeds of 17.2 and 20.1 m/s which are significantly lower than the conventional shut down speed of 25 m/s at that time. So,

given the rarity of very high wind speeds, the higher shut down speeds then in use would reduce the likelihood of this being a problem even further. Thirdly, even if the skilled person did consider implementing Bossanyi in a VSVP turbine in 1995, it was not obvious to reduce the rotor speed. In this connection, the skilled person would know that in region III, fixed speed and VSVP turbines were operated at constant speed. It was therefore not obvious to reduce the rotor speed of a VSVP turbine at wind speeds above the shut down speed.

51. The judge carried out his evaluation in a structured way. He considered first, whether the skilled person would have thought Bossanyi was worth pursuing at all; secondly, whether, given the focus on VSVP turbines in 1995, the skilled person would consider applying the teaching of Bossanyi to such turbines; thirdly, how the teaching of Bossanyi might be implemented; and fourthly, whether the skilled person would think of varying the turbine rotor speed.

52. As for the first point, the judge accepted evidence given by Professor Leith to the effect that the primary focus of the skilled person in 1995 was how to extract maximum power at minimum cost with a reliable turbine. Nevertheless, he continued, the skilled person was not oblivious to the concern that, as wind farms grew larger and contributed a larger share of power to the electricity grid, a simultaneous increase or decrease in power from a cluster, such as that caused by a storm front, might significantly affect the grid. In these circumstances, the skilled person reading Bossanyi would see an improvement of network stability relating to wind energy as a goal well worth pursuing.

53. The second point caused the judge no difficulty at all. He held that, given the focus on the VSVP turbines in the industry in 1995, a skilled person reading Bossanyi would seriously consider applying its teaching about gradual power reduction to a VSVP turbine. This would be entirely obvious.

54. That brought the judge to the third point, namely how the skilled person would think when considering the possible implementation of the gradual power reduction taught by Bossanyi in a VSVP turbine. One possible approach, advocated by Professor Leith, would be to keep the rotor speed constant and gradually to reduce the drivetrain torque and so also reduce the power generated by the turbine. It would not fall within the patent claim, however. Mr Butterfield agreed that this was a possible approach but maintained that another approach would be to maintain the drivetrain torque and gradually reduce the rotor speed. This too would reduce the power generated by the turbine and it would fall within the claim. Mr Butterfield maintained that this would be an obvious approach because the skilled person would be considering loads and fatigue and would understand that a reduction in rotor speed would reduce static and dynamic loading on the turbine. He explained that the skilled person would here have in mind the thrust loading arising from the axial forces acting on all three turbine blades. These forces are transferred through the hub and must be resisted by the turbine structure.

55. This difference between the experts gave rise to a substantial dispute about various calculations performed by Mr Butterfield in an attempt to show that a reduction in speed as well as power would reduce loads on the turbine in high winds, including, in particular, thrust loading caused by gusts of wind. These calculations were criticised by Professor Leith who maintained that Mr Butterfield had made various assumptions

which made his approach unrealistic. The judge addressed these criticisms in some detail and in the end concluded that they did not justify the wholesale discounting of Mr Butterfield's evidence. Further, the judge continued, it was important not to get too distracted by this aspect of the dispute because it was common general knowledge that gusts and turbulence are a greater problem at high wind speeds and that is why it was conventional simply to shut the turbines down at wind speeds above 25 m/s.

56. The judge then expressed his conclusion on this aspect of the case:

> "141. A key thing about the teaching of Bossanyi is that it proposes to the skilled person that a turbine should indeed be kept running at wind speeds higher than the shut down speed; that is to say it should be kept operational while the wind speeds are such that one would normally shut down the turbine to avoid them because of their load and fatigue effects. I do not believe it involves hindsight to see Bossanyi that way. Concerns about loads and fatigue would be of paramount concern to the skilled person precisely because of what Bossanyi is teaching the skilled person to do. At a qualitative level, before performing any calculations at all, a skilled person would know they had to think about the impact of running the turbine at these very high wind speeds and would actively consider how best to do that in a way which mitigated problems of loading and fatigue."

57. This gave rise to the fourth issue, namely whether the skilled person would have the idea of varying the rotor speed when putting Bossanyi into practice. If he did then the judge had no doubt that he would also understand the benefit it would bring, as he explained at [142]:

> "… I am sure they would have a clear qualitative view that reducing rotor speed as well as power as the wind speed rose above the nominal shut down speed, using a ramp rate based on Bossanyi's (b) ramp rate, was likely to mitigate the risks due to loading and fatigue. Detailed calculations would be carried out of loads and fatigue. I infer they would support the view that for a given power ramp rate comparable to rate (b), reducing speed would be advantageous for loading and fatigue as compared to keeping speed constant. I infer the difference would be appreciable."

58. After considering various other submissions advanced on behalf of Wobben, the judge summarised his views on this issue in these terms:

> "146. The skilled person given Bossanyi in 1995 would, without any hindsight, consider implementing it in a VSVP turbine and therefore think about how to implement the ramp down above the shut down speed. The ramp down requires the power to be reduced as the wind speed rises. I find that the options which would present themselves would be (a) to keep torque constant and reducing rotor speed accordingly, (b) to

> keep speed constant and reduce torque accordingly, or (c) to take a course involving aspects of both. These approaches arise from the nature of a VSVP turbine itself and are all obvious things to consider when thinking about implementing Bossanyi in a VSVP turbine."

59. In light of the foregoing the judge's overall conclusion on the issue of obviousness in light of Bossanyi was, I think, inevitable:

> "151. I have dealt with the detailed reasons advanced by each side above. Standing back I think it required no inventive activity at all for a skilled person given Bossanyi in 1995 to think seriously about how to implement the power ramp down proposal in VSVP turbines. They would consider how to put that into practice and, in terms of controls, it was obvious to think about "turning" the electric torque "knob" and the pitch control "knob". Reducing rotor speed as the wind speed increased as a way of reducing power accordingly is not the only way of putting Bossanyi into practice but it is an obvious approach. Reducing the speed this way has an obvious advantage in terms of loading and fatigue."

The appeal

60. Mr Michael Silverleaf QC, who has appeared upon this appeal on behalf of Wobben with Mr Adam Gamsa, has vigorously challenged the judge's approach and conclusions. Recognising the reluctance of this court to interfere with a finding by a trial judge on an issue such as obviousness which requires the judge to evaluate all of the evidence before him, Mr Silverleaf submits that the judge has fallen into a series of fundamental errors.

61. Mr Silverleaf has developed this submission as follows. He argues that the judge failed properly to appreciate that the teaching of Bossanyi relates to fixed rotor speed turbines and that, at the priority date, both fixed speed turbines and VSVP turbines were operated at a set rotor speed once they reached their rated wind speed. Accordingly, he continues, the skilled person thinking of applying the teaching of Bossanyi to a VSVP turbine would follow the common general knowledge approach and operate the turbine in the way that Bossanyi describes, that is to say, by feathering the blades to reduce the power extracted from the wind while maintaining the set rotor speed.

62. Mr Silverleaf continues that VSVP turbines were developed primarily to enable more efficient operation at wind speeds below rated wind speed. Once they reached their rated wind speed and moved into region III, they were operated at constant speed until they reached shut down wind speed. So the method of operation of a VSVP turbine in region III was just the same as for a fixed speed turbine save that it could deal with gusts by allowing its rotor speed to rise slightly and so reduce the mechanical stresses on the rotor and turbine structure.

63. Further, says Mr Silverleaf, there is no need to depart from this approach simply because the wind speed increases above that of normal shut down speed. Bossanyi

teaches a method of continuous operation above normal shut down speed by feathering the blades to reduce the power extracted from the wind. That apart, the operation of the turbine remains as it does in region III. So the skilled person implementing Bossanyi, whether on a fixed speed or a VSVP turbine, would do what Bossanyi teaches and it would not occur to him to do otherwise.

64. Mr Silverleaf contends that, in failing to accept these submissions, the judge made a number of critical errors. The first concerns the evidence of Mr Butterfield and the reliance that the judge placed upon it. Mr Silverleaf has developed this submission in the following way. He highlights Mr Butterfield's evidence that the skilled person would carry out calculations which would lead him to conclude that both the power and the rotor speed of the turbine should be reduced when operating above the normal shut down wind speed in order to reduce the dynamic loads, particularly thrust loads, acting on the turbine and so minimise fatigue. Professor Leith did not agree and advanced a series of criticisms of Mr Butterfield's approach in his second report. One of these concerned Mr Butterfield's choice of ramp rate. Professor Leith explained that this rate was not the same as that taught by Bossanyi. Mr Butterfield chose a ramp in which power was reduced by 50% as the wind speed increased by 10 m/s past normal shut down speed. By contrast, the most gradual ramp considered in Bossanyi involved a power reduction of 100% as the wind speed increased by 3.8 m/s. Professor Leith then carried out the same calculations as those of Mr Butterfield but using Bossanyi's ramp rates and found that these gave load increases which were very much lower than those arrived at by Mr Butterfield. Professor Leith continued that a fair and representative analysis such as that which he had carried out would indicate to the skilled person that ramping down while maintaining rotor speed would not result in any material increase in the thrust loads caused by gusts in the wind as compared to those experienced in normal operation in region III; and further, that the skilled person would have no concerns in implementing the teaching of Bossanyi and maintaining the rated rotor speed.

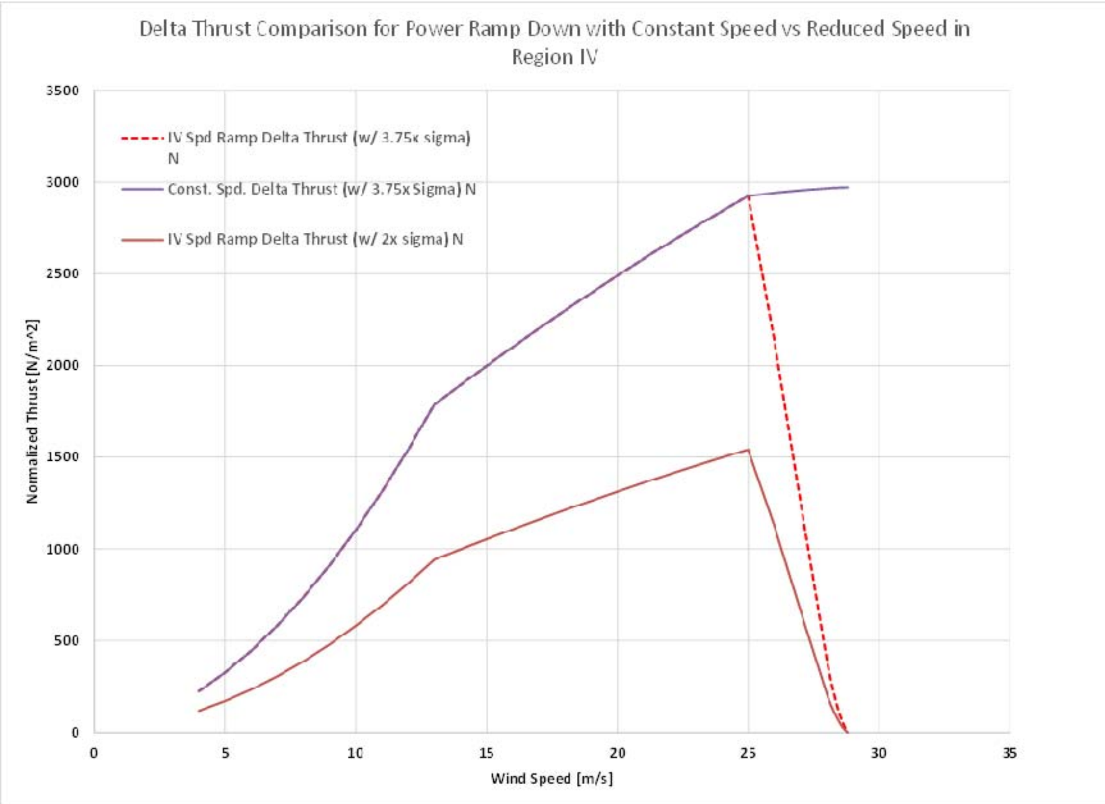
65. Mr Silverleaf submits that, despite finding that Mr Butterfield's calculations used an unjustified and unexplained ramp rate which artificially exaggerated the loads experienced by the turbine, the judge found that the skilled person would consider reducing the rotor speed as well as the power above the normal shut down wind speed. Mr Silverleaf argues that there was no justification for this finding and that the judge ought to have found that the flaws in Mr Butterfield's approach fatally undermined the value of his evidence.

66. I recognise, as did the judge, that the ramps originally modelled by Mr Butterfield were very much shallower than those described by Bossanyi. I also accept that Professor Leith demonstrated that the use of ramp rates closer to the rates proposed by Bossanyi yielded greatly reduced loads on the turbine. Further, Mr Butterfield was not able in cross-examination to explain why he had chosen the ramp rates he had used in his models, and this was something he should have been able to do.

67. That is not the end of the story, however. As Dr Justin Turner QC, who appears with Mr James Whyte on behalf of Siemens, properly points out, Professor Leith accepted in cross-examination that the skilled person implementing the teaching of Bossanyi at high wind speeds would be interested in and have regard to changes in thrust loading - that is to say, dynamic thrust or delta thrust - on the turbine resulting from gusts of wind. Professor Leith agreed too that implementation of Bossanyi ramp (b), that is to

say a ramp width of 3.8 m/s, without a reduction in rotor speed, would lead to an increase in delta thrust.

68. The degree of thrust load variation and how it may be reduced by reducing the rotor speed is, to my mind, well demonstrated by the graph below which formed part of Mr Butterfield's third report and which was put to Professor Leith in cross-examination:



69. The upper solid line shows how delta thrust changes with wind speed for a constant speed rotor presented with a 3.75 sigma gust and with a 100% ramp down in power from 25 to 28.8 m/s wind speed. It is true that, as Professor Leith pointed out, there is only a modest increase in delta thrust above 25 m/s wind speed. However, the dashed line, superimposed by Mr Butterfield, shows the effect upon delta thrust of reducing the rotor speed over the width of the ramp. Professor Leith accepted in cross-examination that the delta thrust now falls in the manner depicted.

70. It is also important to have in mind that, as the judge observed at [130], figure 3 of Bossanyi has been normalised and so makes it clear that it is not concerned with actual absolute wind speed values. A skilled person thinking of designing a turbine with a nominal shut down speed of 25 m/s as opposed to the 20.1 and 17.2 m/s speeds modelled in Bossanyi would therefore find the paper interesting but would not blindly try to replicate the ramp rates it discloses. In all these circumstances I reject the submission that the judge ought to have found that the flaws in Mr Butterfield's approach fatally undermined the value of his evidence. It seems to me that, whilst there were certainly deficiencies in the way Mr Butterfield developed his approach, there was at the end of the day a degree of common ground between his evidence and that of Professor Leith. Further, the judge was, in my view, entitled to step back and consider, as he did, the wider picture. At the priority date turbines were shut down at a

wind speed of 25 m/s to avoid the loads and fatigue associated with running the turbine in higher wind speeds. Bossanyi proposes that a turbine should be kept running above the wind speed at which a turbine would normally be shut down. Concern about the static and dynamic loads and the fatigue experienced by the turbine would therefore be of great importance to the skilled person thinking of implementing Bossanyi's teaching and so he would naturally consider how these problems could be mitigated.

71. Mr Silverleaf points next to the judge's conclusion at [142] that the skilled person would have a clear qualitative view that reducing the rotor speed as well as power at wind speeds above 25 m/s would be beneficial. He submits that there was no evidence to support this conclusion and that the judge was not entitled to rely as he did upon the inference that the necessary detailed calculations would support the view that, for a power ramp comparable to that of line (b) in Bossanyi's figure 3, reducing speed would be advantageous in terms of its impact upon dynamic loading and fatigue. Indeed, says Mr Silverleaf, the judge's reasoning is both conclusory and circular. It relies upon making changes to Bossanyi's ramp rate for which there is no justification, and it then relies upon the conclusions from that defective process of reasoning to justify the further conclusion that the rotor speed as well as power should be reduced.

72. I am satisfied that this submission must be rejected for two reasons. First, I do not accept that Mr Butterfield's evidence concerning the skilled person's implementation of Bossanyi was fatally flawed. As I have explained, the judge was entitled to say that this evidence should not be discounted altogether despite Mr Butterfield's inability to explain his original choice of ramp rate.

73. Secondly, the judge's conclusions had a proper basis in the common general knowledge and the other expert evidence in any event. In that regard it must be borne in mind that it was common general knowledge at the priority date that wind turbines are prone to fatigue from the bending moments applied to the blades and the high number of load cycles to which they are exposed; that the wind conditions in which the turbine will be operating and the dynamic loads to which it will be exposed are highly important considerations for any designer; that the frequency, magnitude and power of wind gusts tend to increase with an increase in average wind speed; and that the normal practice of shutting a turbine down at a wind speed of 25 m/s reflected a balance between the benefit of continuing to operate the turbine at higher but increasingly rare wind speeds and the cost of the measures necessary to make the turbine robust enough to cope with the loads and fatigue it will experience. As the judge went on to hold, it was also part of the common general knowledge that the principal reason for shutting down a VSVP turbine in extreme winds was to protect the turbine from the effects of dynamic loading and the fatigue that these effects may generate; and further, that the dynamic thrust loads are one area of particular concern. As Mr Butterfield explained at length in his first report, the skilled person would recognise that reducing the power and rotation speed of a turbine in high wind conditions will reduce the thrust loads on the turbine and will also provide additional tolerance or head room by reducing the risk that turbulence will cause the turbine to rotate at above its rated speed, a condition sometimes referred to as "overspeed".

74. Wobben also challenges the judge's findings on two further grounds: first, that the skilled person's motivation to apply Bossanyi would be weak because cluster power

output ramps were not a concern at the priority date, largely because wind energy was not being generated on a large enough scale for such power ramps to affect the grid; and secondly, it would not be obvious to apply Bossanyi to VSVP turbines, not least because the shut down speeds had increased to 25 m/s, well above the ends of the ramp strategies it describes.

75. In developing these grounds, Mr Silverleaf has emphasised the rarity of wind speeds higher than 25 m/s. Further, he points to the fact that the maximum shut down speed modelled by Bossanyi is substantially lower than the 25 m/s normal shut down speed at the priority date. So, he continues, the teaching of Bossanyi offers no improvement over standard practice by the priority date and the rarity of higher wind speeds of 25 m/s or more means that Bossanyi's frequency analysis could have no application to the real environment, as the skilled person would readily appreciate. What is more, says Mr Silverleaf, the skilled person would know that any serious consideration about whether to keep the turbine operating at wind speeds above 25 m/s would require a complicated design exercise involving detailed fatigue cycle analysis. The teaching of Bossanyi would therefore be of no practical interest.

76. I am satisfied there is nothing in either of these grounds. The judge found that the skilled person was not oblivious to the concern that, as windfarms grew larger and contributed a larger share of power to a grid, a ramp in the power output from a cluster such as might be caused by a storm front would significantly affect the grid. There had been a rapid growth in wind energy through the 1980s and 1990s which, so the judge found, was set to continue. In these circumstances, I am satisfied the judge was entitled to find that the skilled person reading Bossanyi would see the goal of improving network stability as one which was well worth pursuing.

77. The judge also had well in mind that the data used in Bossanyi were not sufficient to allow an analysis of the effect of imposing a shut down speed of 20.1 m/s. It was for this reason that Bossanyi used the lower shut down speed of 17.2 m/s. The judge was conscious too that the likelihood of a significant ramp in power output from a wind farm will reduce as the shut down speed rises. Nevertheless, I am satisfied that the judge was right to say that the skilled person would see this aspect of Bossanyi's teaching as a general one. Bossanyi says in terms that, if the wind turbine can be controlled in such a way as to bring the power output gradually down to zero in high wind speeds, the situation is improved both for the individual windmill and also for the cluster by reducing severe power ramping in cluster output. This teaching is applicable whatever the normal shut down speed may be and even if an event which causes it is likely to occur only rarely. The strategy will still reduce the risk of the grid experiencing the effect of a ramp in the cluster power output.

78. There are two other points with which I must deal. Mr Silverleaf says, correctly, that the judge rejected the evidence of Mr Butterfield that it would have been obvious to reduce the rotor speed of a VSVP turbine prior to shut down in light of the common general knowledge alone. Put another way, it would not have been obvious in light of the common general knowledge alone to operate a VSVP turbine other than in the normal way, that is to say by maintaining constant rotor speed and reducing the torque. Accordingly, Mr Silverleaf continues, in finding that it would be obvious to reduce the rotor speed in light of Bossanyi, the judge must have found in that paper a motivation for reducing the rotor speed. But there is nothing in Bossanyi to that effect because it is a study of fixed speed turbines.

79. It seems to me that this is just another way of developing the arguments which I have already addressed. The judge was well aware that the whole teaching of Bossanyi concerns fixed speed turbines. Those were the prevalent turbines in 1982, the date of its publication. However, the most relevant aspect of its teaching is not concerned with the nature of the turbine; it is concerned instead with the operation of the turbine at wind speeds above the normal shut down speed. By the priority date, the industry had moved on. It was now focused on VSVP machines and these had the ability to decouple the generator speed from the frequency of the grid and so vary the rotor speed. In these circumstances, the two critical questions in the obviousness analysis were whether the skilled person would see anything in Bossanyi worth pursuing and implementing and, if so, how that would be done. The judge answered both of those questions in the manner I have described and I do not think he can fairly be criticised for so doing.

80. The second point is this. Mr Silverleaf argues that Siemens' whole approach to the issue of obviousness is driven by hindsight. If the skilled person implementing the teaching of Bossanyi at the priority date in a VSVP machine would not have reduced power alone due to his concerns about loads and fatigue then he would never have implemented it on a fixed speed turbine such as the Mod-2 which is the very focus of the Bossanyi study. Accordingly, Siemens' case would then have to be that the skilled person, recognising that Bossanyi could not be implemented safely in the Mod-2, would nevertheless have considered implementing it in a different way by reducing rotor speed in a different turbine. This, says Mr Silverleaf, is a deeply unattractive case, as the judge should have recognised.

81. I believe the flaws in this argument are not difficult to see. Siemens did not contend that Bossanyi could not be implemented in a fixed rotor speed turbine, whether in 1982 or in 1995. Nor was it suggested that Bossanyi could not be implemented in a VSVP turbine by reducing power but maintaining a fixed rotor speed. It was instead contended, and the judge accepted, that it would have been obvious to the skilled person in 1995 to make use of the variable rotor speed feature of the VSVP turbine and that this would confer an additional benefit of reducing the dynamic thrust loads to which the turbine would be exposed if it were to operate above the normal shut down wind speed of 25 m/s.

82. In my judgment the judge was entitled to hold that the skilled person given Bossanyi in 1995 would consider implementing it on a VSVP machine and so would think about how to implement the ramp down above the normal shut down speed. That requires the power to be reduced as the wind speed increases and the skilled person would appreciate that this could be achieved by keeping the torque constant and reducing the rotor speed; by reducing the torque and keeping the rotor speed constant; or by reducing both the torque and the rotor speed. These findings had a proper basis in the evidence and the judge has made no error of principle in his reasoning. Mr Silverleaf has not established any ground upon which it would be appropriate for this court to interfere with the judge's evaluation of the evidence or to set about re-evaluating that evidence for itself.

83. I would therefore dismiss the appeal against the judge's finding that the patent was invalid for obviousness.

Infringement

84. The element of the Siemens' VSVP turbines which was said to give rise to infringement is called High Wind Ride Through (HWRT). It reduces the speed of rotation and the power output of the turbine in high speed wind conditions. There was no dispute about how it works and its essential features may be summarised as follows.

85. HWRT is turned on when the wind speed rises above a certain threshold. It controls the turbine power and rotor speed but it does so in different ways. The algorithm for controlling power calculates a filtered moving average of the pitch reference, a value representing the desired pitch angle of the rotor blades. A power limit is imposed based upon this moving average. The higher the average pitch reference, the more the power limit is reduced. The pitch reference is effectively a measure of the wind speed and so this aspect of HWRT does satisfy the requirements of claim 1 of the patent. Once the wind speed is in danger of overloading the turbine, the power of the turbine is continuously reduced "in dependence on" the rise in the wind speed.

86. The rotor speed is adjusted by the HWRT system depending upon the gustiness or turbulence of the wind, that is to say how fast the wind is changing. The system calculates the acceleration or deceleration of the rotor using sample readings taken 200 ms apart. An absolute value is determined (acceleration and deceleration are treated in the same way) and is then subjected to a filtering process. If the result of this filtering process, the filtered rotor acceleration, exceeds a threshold level, referred to as a bias, the rotor speed is reduced accordingly.

The judge's assessment – an outline

87. Wobben recognised at trial that, in simple mathematical terms, acceleration is not a measure of speed but argued that this case was about a time course of measurements, and that this was a very different matter. It contended that the evidence showed that HWRT does in fact reduce rotation speed as wind speed increases and that this is because filtered rotor acceleration is a measure of the wind speed the rotor is experiencing. Accordingly, wind speed is being used to control the rotation speed, and that the speed is continuously reduced "in dependence on" the rise in the wind speed.

88. Siemens responded that the system reduces rotor speed in response to an acceleration or deceleration of the rotor, not the wind speed. Moreover, wind can be turbulent or smooth. If the wind is blowing at high speed but smoothly, there will be no acceleration or deceleration and HWRT will not reduce the rotor speed. If, however, the wind is blowing at a slower speed but is more gusty and turbulent, the rotor will accelerate and decelerate and HWRT will reduce the rotor speed. It accepted that the magnitude and frequency of gusts tends to increase with an increase in wind speed but maintained that this was nothing to the point: the speed of rotation set by HWRT is based upon rates of change in the wind speed and not upon the wind speed itself. Accordingly, there could be no infringement.

89. The judge dealt first with the meaning of the patent claim and he made the findings which I have summarised at [32] above. He then proceeded to assess Wobben's infringement case. After considering a good deal of the evidence of Professor Leith and Dr Santos, to some of which I shall have to refer in addressing Mr Silverleaf's submissions on this appeal, the judge said this at [204]:

> "The infringement issue has involved a large number of quite complex points but in the end I believe it can be dealt with in this way. A major part of Wobben's case here is about the nature of the wind itself as experienced by a turbine rotor as a whole rather than an argument about how HWRT works. As to that Prof Leith accepted the following in cross-examination:
>
> Q. And an increase in wind speed, which does not produce a filtered acceleration above the bias, will not trigger a call for speed reduction.
> A. That is correct.
> Q. So it follows that during a period of relatively low turbulence, wind speed can increase without calling for a reduction in rotor speed.
> A. Depending on the numbers, in principle, yes."

90. As the judge went on to explain, the infringement case was nevertheless pressed, not because Professor Leith was wrong in accepting these propositions, but because Wobben maintained that the factual premise of the questions he was asked had not been established. As to that, the judge summarised certain evidence given by Professor Leith in these terms:

> "206. I return to the common ground that turbulence will tend to increase with wind speed. Prof Leith accepted that on some days one can have a smooth strong wind while on other days one can have a similarly strong wind which is very gusty. He was asked about his knowledge of the factors which affect turbulence and the Professor accepted that there are many other factors that affect turbulence as well. He agreed that turbulence can vary from day to day, and is affected by wind direction due to topographical features. He did not know about the effect of sea waves, but agreed that surface roughness would affect the wind, particularly closer to the surface. He also did not know about diurnal effects or varying turbulence with the passage of a storm."

91. It followed that, despite the common ground as to the tendency for turbulence to increase with wind speed, the filtered rotor acceleration used by HWRT was not in fact a measure of wind speed:

> "207. I do not accept that the evidence in this case bears out Wobben's submission on the facts. In my judgment, in the relevant conditions, it is possible for the wind speed as experienced by the rotor to change gradually and smoothly over time in such a way that filtered rotor acceleration measured by HWRT will not change. I find that this is a realistic state of affairs irrespective of the particular approach to considering wind speed one might take, however it might be averaged and taking into account the rotor as a whole, including rotational sampling. If the wind speed can rise without a corresponding rise in turbulence over the timescale relevant for the filtered

> rotor acceleration measurement, it follows that in such a case HWRT will not reduce rotor speed depending on a rise in wind speed. In other words the filtered rotor acceleration used by HWRT is not a measure of wind speed."

92. The judge concluded at [208] that HWRT reduced rotor speed in dependence on a rise in absolute filtered rotor acceleration in order to protect the turbine from dynamic loads associated with accelerations and decelerations. It was not meaningful to say that HWRT was using filtered rotor acceleration as a surrogate for wind speed.

The appeal

93. Mr Silverleaf begins with the proper interpretation of the patent claim. He accepts that the phrase "in dependence on" means that the reduction in the speed of the rotor must depend on the rise in wind speed but submits that the judge went too far in saying that there must be a causal relationship between the two.

94. I am not entirely sure what the judge meant by a causal relationship in the context of this patent. If he meant that the wind speed must be measured directly then I respectfully disagree with him. Purposively what matters is that as the wind speed rises above a level which may imperil the turbine, the rotor speed is continuously reduced. In those conditions, the rotor speed must be determined by and be contingent upon the wind speed. Whether that correlation is effected by a direct measurement of the wind speed or a surrogate does not seem to me to make any practical difference. Nevertheless, I am satisfied this does not affect the ultimate conclusion to which the judge came, as I shall explain.

95. Mr Silverleaf then reiterates the case that Wobben advanced before the judge. He submits that, with increasing wind speed, the turbine blades will experience increased gustiness. In HWRT controlled turbines, larger and more frequent gusts cause larger and more regular accelerations and decelerations of the rotor, and these manifest themselves as larger and more frequent filtered rotor accelerations. Filtered rotor acceleration is therefore in practical terms a surrogate for wind speed and it is meaningful to say that the rotor speed depends upon the wind speed.

96. It seems to me that the difficulty Mr Silverleaf faces is that this case depends on the facts and the judge was simply not persuaded that, having regard to the particular way that HWRT operates, filtered rotor acceleration is a surrogate for wind speed. Nevertheless, he has sought to satisfy us that the judge wrongly evaluated the evidence before him. In that regard he has taken us to various aspects of that evidence, each of which I will now address.

97. I begin with a paper by Nicolaos Cutululis, Martin Bjerge and others entitled *Impact of High Wind Speed Shut-Down in the Danish Power System* presented in 2013 at the 12th Wind Energy Workshop in London. Martin Bjerge was at that time employed by Siemens Wind Power in Denmark. The paper says this about the HWRT controller:

> "HWRT allows production at higher wind speeds than earlier by de-rating the power and speed gradually as the wind speed increases."

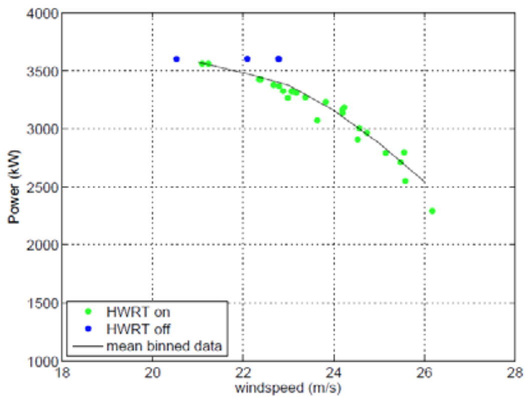
A little later, it continues:

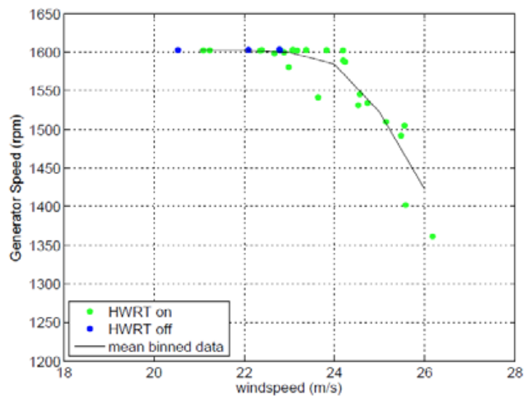
> "The first mode of operation reduces the rotational speed of the turbine based on the rotor acceleration. This is done by converting the current rotor speed to absolute acceleration. The acceleration value is multiplied by a gain to give a speed reduction. As wind speed change increases (turbulence), the rotor acceleration increases and therefore results in a gradual speed reduction."

98. Mr Silverleaf submits that the meaning of this passage is clear and that it strongly supports Wobben's case. The same submission was advanced at trial and the judge was not much impressed by it. He accepted Siemens' submission that the second paragraph is entirely accurate in that it explains that speed is adjusted in dependence upon rotor acceleration. In other words, it is the rate of change in wind speed which is operative in HWRT, not the wind speed itself. He thought that, read as a whole, the paper did not support Wobben's case and that the first paragraph of the cited passage could be seen as loose wording.

99. I believe the judge's analysis of this paper is fair and correct. The paper does not purport to provide a full explanation of how HWRT operates and cannot therefore be seen as some kind of acceptance by Siemens that the rotor speed is dependent upon the wind speed. The judge had the benefit of a full product and process description and expert evidence which together provided him with a much more secure foundation for his evaluation.

100. In that regard we have been taken by Mr Silverleaf to the evidence given by Professor Leith in his first and second reports to the effect that wind speed and gusts are not independent of each other and that an increase in average wind speed tends to be accompanied by an increase in gustiness. Professor Leith continued that larger gusts acting on the turbine blades will tend to lead to greater acceleration of the rotor. He sought to demonstrate this by reference to a number of figures. Two of those discussed in the judgment are reproduced below:





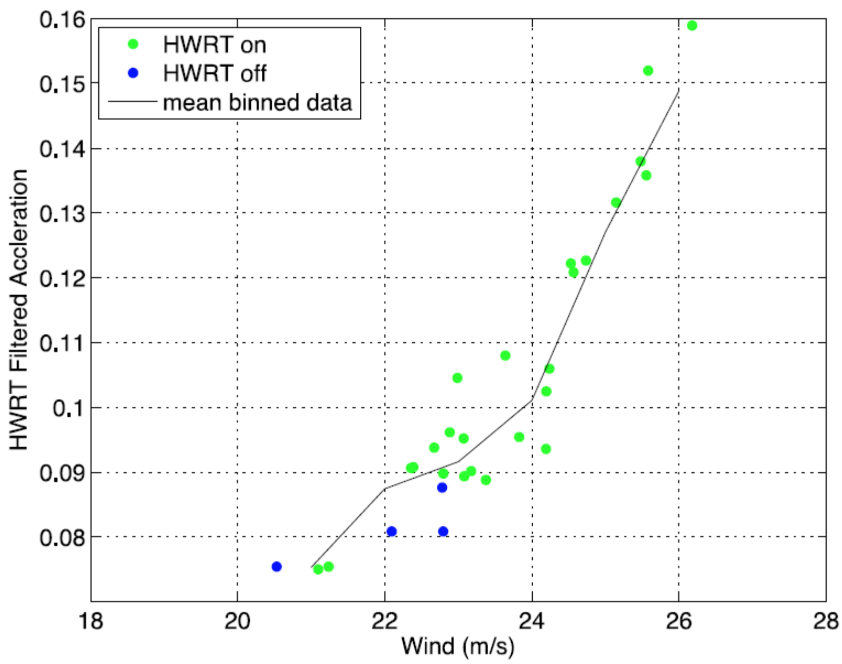
101. These are graphs of generator power (on the left) and generator speed (on the right) plotted against wind speed (and they are figure 18 in Professor Leith's first report). Mr Silverleaf accepts that the data are 'noisy' but submits that they demonstrate a correlation between generator power and generator speed, on the one hand, and wind speed on the other.

102. We are, of course, only concerned with the relationship between generator speed and wind speed. However, the difficulty with the generator speed graph, as Dr Santos explained, is that it is based on data which have been "binned". The wind speed values are 10 minute average values measured by an anemometer on the nacelle of the turbine. No doubt such binning is entirely appropriate for some purposes. However, the speed setting part of HWRT operates over a period of seconds and the filtered rotor acceleration value is based upon a weighted average in which a significant part of the weighting comes from the most recent 15 seconds. Dr Santos elaborated upon this point in his cross-examination. He estimated and the judge accepted that HWRT spends a substantial amount of time at the rated generator speed and that it has excursions down to a lower speed which may last for no more than one or two minutes.

103. In these circumstances it seems to me that the judge was entitled to say at [180]:

> "Accordingly I will not place weight on the plots of generator speed against 10 minute average wind speed … The binned average of generator speed over a 10 minute period which is shown in the right hand plot above does not fairly represent what is actually going on."

104. The same observations may be made about another graph to which Mr Silverleaf referred us (figure 22 in Professor Leith's first report). In this case Professor Leith plotted the 10 minute mean wind speed, again measured by an anemometer on the nacelle, against a 10 minute mean of the filtered rotor acceleration:



105. Again, the 10 minute averaging conceals how HWRT is in fact operating. In a single 10 minute period (represented by a single dot in Professor Leith's plot) the HWRT algorithms may have been responding to a series of filtered rotor accelerations arising from gusts of wind. When a gust hits the rotor, resulting in an increase in filtered rotor acceleration, the speed of the rotor is reduced. When the gust subsides, the rotor is

allowed to return to normal speed. Moreover, these speed excursions drag the average rotor speed down (or lift the filtered rotor acceleration up) with the consequence that the average does not give a fair reflection of what the rotor speed (or filtered rotor acceleration) has actually been doing for a good deal of the time.

106. Finally, Mr Silverleaf takes issue with the judge's findings in his judgment at [206] and [207] which I have cited above at [90] and [91]. He submits that they have no foundation in the evidence and are contrary to the agreed common general knowledge that the magnitude and frequency of gusts increases with an increase in average wind speed.

107. I cannot accept these submissions. It is of course true that size and the frequency of wind gusts and turbulence tend to increase with an increase in the wind speed. We have been taken in the course of argument to a good deal of the cross-examination of the experts and in my judgment the judge's findings do fairly reflect and are properly based upon the evidence the experts gave. In particular Professor Leith accepted that there will sometimes be a strong wind which is very smooth and at other times an equally strong wind which is very gusty. Moreover, turbulence can be affected by local geography and wind direction. Conversely, Professor Leith also accepted that during a period of relatively low turbulence it is possible that a gradual increase in wind speed will not produce a filtered acceleration in the HWRT algorithm which would trigger a speed reduction.

108. At the end of the day this case is concerned not with the general tendency of gustiness to increase with an increase in average wind speed but with the operation of HWRT and whether it may fairly be said that the operating speed of the rotor is continuously reduced in dependence upon the rise in the wind speed. This requires a consideration of both the way in which and the level at which the control algorithms in HWRT work. For the reasons I have given, I believe that the judge was entitled and indeed right to find that HWRT reduces rotor speed in dependence upon a rise in filtered rotor acceleration and that it does so to protect the turbine from dynamic loads associated with accelerations and decelerations. HWRT is not using filtered rotor acceleration as a surrogate for wind speed.

Conclusion

109. I would dismiss this appeal.

Lord Justice Floyd:

110. I agree.

Lord Justice Longmore:

111. I also agree.