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Case No: HP-2013-000014
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IN THE HIGH COURT OF JUSTICE
CHANCERY DIVISION
PATENTS COURT

Royal Courts of Justice, Rolls Building
Fetter Lane, London, EC4A 1NL

Date: 20/07/2015

Before :

MR JUSTICE BIRSS

- -

Between :

WOBBEN PROPERTIES GmbH	**Claimant**
- and -	
(1) SIEMENS PLC **(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**

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Andrew Lykiardopoulos QC and **James Abrahams** (instructed by **Powell Gilbert LLP**) for the **Claimant**
Justin Turner QC and **James Whyte** (instructed by **Bristows LLP**) for the **Defendant**

Hearing dates: 19th, 22nd, 23rd, 24th, 30th June and 1st July 2015

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Approved Judgment

I direct that pursuant to CPR PD 39A para 6.1 no official shorthand note shall be taken of this Judgment and that copies of this version as handed down may be treated as authentic.

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MR. JUSTICE BIRSS

Mr Justice Birss :

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Introduction

1. This case is about wind turbines. The claimant (Wobben) holds patent EP (UK) 0 847 496 entitled "Method of Operating a Wind Power Station". The patent claims priority from a German filing on 1st September 1995. The patent was granted on 9th August 2000. Wobben contends that the defendants have infringed the patent by installing wind turbines in the UK. Particular installations relied on include the off-shore sites at the London Array, Westermost Rough and Gunfleet Sands. Before me Wobben estimated the value of this action as of the order of £13 million.

2. It is convenient to refer to the defendants collectively as Siemens. Siemens denies infringement and contends that the patent is invalid.

The issues

3. The authentic text of the UK patent is German. There is an agreed translation.

4. Wobben contends that a particular feature of the Siemens wind turbine technology infringes the patent. The feature is called High Wind Ride Through (HWRT). There is no debate about exactly how HWRT works but there is an argument about whether it falls within the claims.

5. Siemens relies on two items of prior art:

    i) A Japanese application filed in 1980 and published in 1981 as JP 56-150999 ("**Shozaburo**").

    ii) The article "*Probabilities of sudden drop in power from a wind turbine cluster*" written by E.A. Bossanyi and published in September 1982 ("**Bossanyi**").

6. Shozaburo is cited for novelty and lack of inventive step. Bossanyi is relied on for lack of inventive step only. Up to trial Siemens had also relied on a United States patent dating from 1855 (US 13, 247 "**Frantz**") but this was dropped. Insufficiency was pleaded but all those arguments have either fallen away or no longer appear to be advanced.

7. Wobben has applied to amend the claims in various ways. Its position was clarified following a pre-trial review. Wobben sought some unconditional amendments and advanced others conditionally. By the opening of the trial the position resolved down to two sets of claims, referred to as a Main Request and an Auxiliary Request. By closing there was no need for Wobben to maintain the amendments in the Auxiliary Request and Siemens did not object to the amendments set out in the Main Request in Annex 1 (which includes deletion of claim 3). The amendments are shown underlined and struck through as compared to the granted claims.

8. Wobben contends that claims 1 and 4 are independently valid. The court need not consider claim 2.

9. An uncontentious amendment is sought to the German language version of the claims. That is because they contain an obvious typographical error in which some English wording has been inserted by accident. It was not opposed. I will allow the amendments in the form sought by Wobben in the Main Request and to correct the typo on the German language claim.

The witnesses

10. Wobben called expert evidence from Professor Douglas Leith. Prof Leith is a Professor in the School of Computer Science and Statistics at Trinity College Dublin. At the priority date, he worked within the Industrial Control Unit at the University of Strathclyde. At the time, this group was one of the leading research groups in the UK on wind turbine control and was an international centre of excellence. The group at Strathclyde always had strong industry links and Prof Leith's projects were in part sponsored by industry including Wind Energy Group (WEG) and Renewable Energy Systems (RES). Prof Leith dealt with both validity and infringement.

11. Prof Leith gave his evidence fairly, clearly aiming to assist the court. Siemens did contend that the Professor was not well positioned to deal with the issues for various reasons I will address. Before doing so I will mention Siemens' submission that one aspect of his evidence was "not satisfactory". This related to what Siemens called the witness's rigidity of approach in relation to whether there was a convention relating to turbine shut down at the priority date. Prof Leith's evidence was not unsatisfactory. He explained his genuinely held opinion on this point and gave reasons for it. I reject the submission that anything can be made of long pauses which counsel submitted occurred at certain points in his cross-examination. Any pauses by Prof Leith made no impression on me other than being the result of the expert taking proper care about his answers.

12. Siemens refers to mistakes Prof Leith is alleged to have made. They are best addressed in context.

13. As regards the expert's position, the major submissions were:

    i) that Prof Leith was unaware of any commercial variable speed, variable pitch turbine (VSVP) turbines which were operating at the priority date (large or small).

    ii) that Prof Leith rigidly adhered to a view about how turbines were operated in high winds which was unjustified.

14. As to the first point, Prof Leith's first direct experience of working on a VSVP machine was the design project which started in 1996 (or 1995) for a VSVP machine for the company RES. What I understood Prof Leith to have explained in cross-examination (transcript $T1/84_{10\text{-}12}$) was that before 1996 (or 1995) he knew about the concept of VSVP machines and how they worked. As I understood his evidence as a whole, he was not concerned with and did not know the details of any commercially operational VSVP machines at the priority date. That reflects his experience and role as an academic albeit one with close links to the industry at the relevant time.

15. There is nothing in the second point. As I shall address below, the normal way turbines were run in high winds was clear in the evidence. Prof Leith was not inappropriately inflexible on this.

16. Overall I thought that Prof Leith's evidence was given from a position of genuine knowledge and experience of the issues of control engineering relating to wind turbines. He was in a position to assist the court in that respect. I also have in mind that he left the industry well before this case and so in a sense his knowledge is uncontaminated with knowledge of later developments.

17. Siemens called expert evidence relating to validity from Mr Charles Butterfield. Mr Butterfield holds a BSc and MSc in Mechanical Engineering from the University of Massachusetts. In 1980 he co-founded a wind turbine manufacturing company and from 1986 he worked at the National Renewable Energy Laboratory (NREL), a US wind technology research and development laboratory. By 1994 he was the Chief Engineer of NREL's National Wind Technology Center. In 2010 he founded his own start-up company focussed on direct drive generators.

18. Mr Butterfield gave his evidence fairly, clearly aiming to assist the court. Wobben submitted he was dogmatic, could not entertain the possibility that others might not have thought as he did and had not taken a proper approach to common general knowledge because he had not gone back and checked his views against the documents. Mr Butterfield did not seem dogmatic to me. I reject the submission that he can be criticised for his approach. He clearly had a wealth of practical experience in the industry. Evidence of common general knowledge may come from textbooks but in a practical field textbooks do not necessarily reflect what those actually working in the art knew or thought. Mr

Butterfield's approach was not inappropriate. I will deal with Mr Butterfield's evidence about shut down speed in context.

19. Mr Butterfield explained in cross-examination that he first heard about the Wobben patent long before this case, in the early 2000s and was not impressed. This does not disqualify him from giving evidence. Wobben submitted that Mr Butterfield's approach to the prior art was flawed because he read Bossanyi and Shozaburo knowing that this was a dispute about different shut down techniques. I agree with Wobben that it is incumbent on an expert to put him or herself back into the correct frame of mind at the priority date. I am sure that Mr Butterfield did so. The submission that he "did not wrestle with any of this" is unwarranted.

20. Wobben criticise Mr Butterfield for denigrating Prof Leith at one point. The tone of Mr Butterfield's remark at the time was beneath him but has no wider significance and Mr Butterfield immediately said sorry. This is a tiny point, only mentioned to be dismissed.

21. On infringement Siemens called Dr Richard Santos. He completed his MSc in 1990 at Syracuse University and has a PhD in aerospace sciences from the University of Colorado relating to "Damage Mitigating Control of Wind Turbines" (2007). Between 1997 and 2004 he worked at NREL on certification and design evaluation of wind turbines. From 2004 to 2007 he worked at Alstom on research and certification of multi megawatt turbines and since 2007 has worked as a consultant on wind turbine dynamics and control.

22. Wobben criticised Dr Santos in various respects. I will deal with most of the points in the context in which they arise. Some of them are justified, although not all. A point which does not arise later is Wobben's submission that his first report took no account of actual conditions. That is not a fair criticism. The report does recognise the actual conditions and also includes explanations at a higher level in order to help the reader understand the point being made.

23. Overall Dr Santos did descend into argument a number of times. This was not at a level which would justify discounting his evidence altogether but it is something I will keep in mind.

24. The only other evidence relied on was the subject of Civil Evidence Act Notices served by Wobben to rely on documents from Siemens (i.e. the first three claimants).

The skilled person

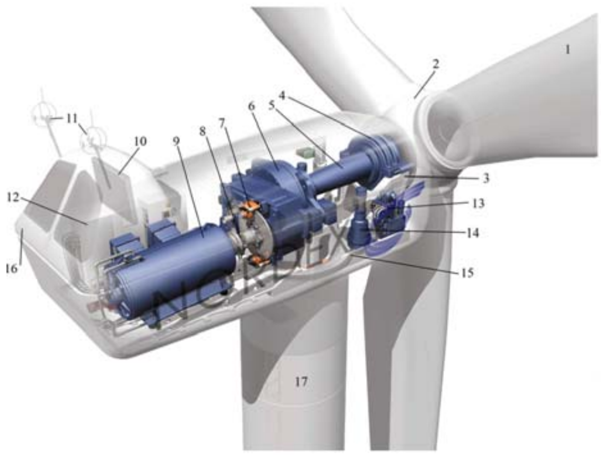
25. There was some debate about the identity of the person skilled in the art, Wobben contending that the patent was addressed to a wind turbine control engineer (supported by Prof Leith) with Siemens contending that the skilled person would have been a more general wind turbine engineer referred to as a systems engineer (supported by Mr Butterfield). In the latter case the skilled person would obtain input from a control engineer. Both a systems engineer and a control engineer have similar backgrounds and both are interested in control aspects of the turbine.

26. I prefer Siemens' formulation for three reasons. First, the task of the skilled person (or team) is to design and build a wind turbine which operates in a particular way. That team will include individuals with various skills. It will include an engineer concerned with control. Whether that person is a specialist control engineer of the kind identified by Prof Leith or a more general engineer with significant control experience makes no difference. Second, the patent is concerned with running a turbine at high wind speeds. This has implications for overall turbine design as well as for control engineering and reinforces the first point. Third, the patent is written at a general level and is not about the detailed design of control systems.

Common general knowledge

27. I will take the law on common general knowledge to be that in the statement made by Arnold J in ***KCI Licensing Inc v Smith & Nephew plc*** [2010] EWHC 1487 (Pat) at paragraphs 105 – 115 which was approved by the Court of Appeal [2010] EWCA Civ 1260 at paragraph 6.

28. In 1995 most wind turbines were designed with the blades rotating on a horizontal axis. Prof Leith included the following schematic diagram in his first report:



29. This illustrates some of the basic elements of a horizontal axis wind turbine. The rotor blades (1) are mounted on a rotor hub (2). The rotor shaft (5) runs through the main bearing (4) to a gearbox (6). Some "direct drive" designs have no gearbox. There is a generator (9) and wind sensors (11). Most of the equipment is mounted in a nacelle with a cover (16) and a frame (3). The nacelle is mounted on a tower (17) via a yaw bearing (15). This is an upwind design, that is to say the rotor hub is upwind of the nacelle when in operation. An alternative is a downwind design in which the rotor hub is downwind of the nacelle in operation. In 1995 upwind designs were the norm.

30. The power available from the wind is proportional to the cube of the wind speed. The wind speed varies over time. One can measure the typical probability distribution of wind speeds in a given location. Wind speeds above 20 m/s become increasingly rare whereas wind speeds around 10 m/s are common. A wind speed of 25 m/s is about force 10 on the Beaufort scale.

31. Generators were designed to have a maximum rated power. Smaller wind turbines have power rating measured in a few or tens of kW. This was true both well before 1995 and afterwards. By 1995 commercially sized wind turbines were capable of generating a maximum power output of 300 - 600 kW. Today wind turbines are much bigger. The Siemens products in issue include designs rated from 2.3 MW to 6 MW.

32. Exceeding the rated power can lead to over heating and other potential damage and so at higher winds it is necessary to limit the power captured by the turbine. This could be by active or passive control. Passive control could be achieved by holding the pitch angle of the blades fixed whereby the blades stall automatically as the wind speed rises. For active control there were two main approaches in 1995: yaw control and pitch control. With yaw control, although normally the turbine is oriented into the wind to maximise effective rotor area, the rotor could be turned out of the wind. With pitch control the angle of the blades is adjusted to control the power extracted from the wind. As the wind speed increased blades could be pitched into the wind (feathered) in order to reduce aerodynamic lift and limit the power captured from the wind. Alternatively as the wind speed increased blades could also be turned out of the wind to induce a stall.

33. Another form of active control is generator control. This relates to the control of the generator torque and is possible when power electronics are coupled to the generator. It was used at high speeds to limit the amount of mechanical power converted into electrical energy.

34. It is necessary to mention the difference between constant speed and variable speed turbines. By 1995 the majority of turbines were constant speed turbines (either fixed pitch or variable pitch) but another kind of turbine in the common general knowledge was a variable speed, variable pitch turbine. This latter design was becoming popular.

35. As its name suggests, a constant speed turbine rotates at a single speed. Once there is sufficient wind to make generating electricity worthwhile, the turbine would be connected to the grid and the rotor would rotate at a constant rate effectively determined by the grid. There were synchronous generators with a rotation rate closely matched to the grid frequency and induction generators in which the rate was within a few percent of constant speed. As the wind speed increased, the power increased until rated power was reached. When the wind increased beyond rated wind speed, the power generated would be held constant e.g. by yawing, pitching or stalling etc. to limit the wind power captured. In effect at wind speeds beyond the rated wind speed, there is more power available in the wind than the rated power of the turbine and the priority is to control the system to regulate how much power to capture in order to maintain rated power and limit loads.

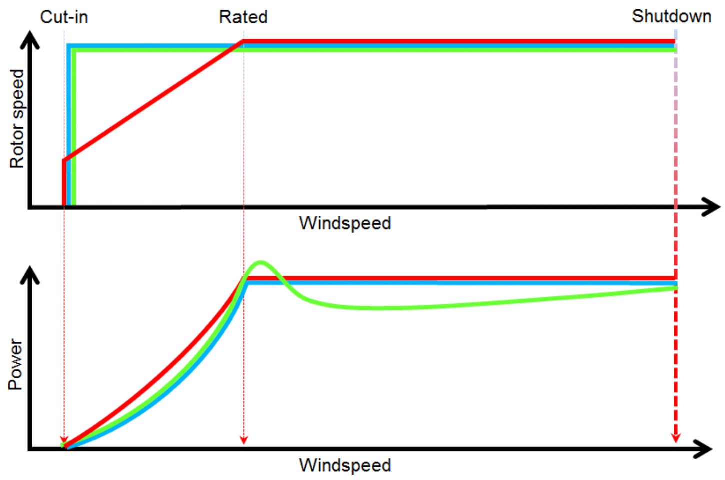
36. Variable speed turbines have a variable rotation speed. They have power electronics to decouple the generator speed from the grid frequency. One example is an AC-DC-AC system in which the generator generates AC current at a variable frequency determined by the speed of rotation. The electronics includes a power rectifier to produce DC which then drives an AC generator

synchronised to the grid. Thus the speed of the generator is unchained from the grid frequency.

37. By the priority date variable speed turbines in which the pitch of the turbine blades could be altered were well known and available commercially. These are called VSVP turbines. They were described in the evidence as "both new and old" in 1995 because the idea was old but commercialisation had been held back by the cost of power electronics. By the 1990s the lower cost of power electronics was making VSVP machines economically feasible.

38. In a variable speed variable pitch turbine the skilled person can vary the electric torque using the power electronics and can vary the blade pitch to change the lift and thereby change the rotor speed. This was described in evidence as the operator having "two knobs to turn".

39. Prof Leith produced diagrams showing the relationship between wind speed, rotor speed and power for constant speed and variable speed turbines:



The diagrams only make sense in colour. Red is a VSVP turbine. Green is a constant speed, stall regulated turbine. Blue is constant speed, pitch regulated turbine.

40. The region marked "Shutdown" on the right is the main area of dispute in this case. I will return to that below.

41. The top graph shows rotor speed as a function of wind speed. Below the cut in speed no power is generated. At and just above the cut-in wind speed (top diagram, left hand side) the constant speed turbines rotate at the constant speed whereas the VSVP turbine starts rotating at a lower speed which rises with wind speed. The power is shown in the lower graph. At wind speeds between cut-in and rated, the power increases from zero as wind speed increases but the red power line is above the green and blue lines because in this region the variable speed system is more efficient. This region was referred to at trial as region II (with region I being wind speeds below cut-in). Above the wind speed marked as "rated", all three systems rotate at constant speeds. There is a difference in power curves between pitch and stall regulation with constant speed machines (green and blue lines) but this does

not matter. The region above rated wind speed and below shut down was referred to at trial as region III.

42. There was a dispute about the behaviour of turbines when the wind speed was below the cut-in speed. Prof Leith said the rotor was generally kept still whereas Mr Butterfield said one option was to allow the rotor to idle by turning with the wind. In my judgment both approaches existed and were part of the common general knowledge.

43. Mr Butterfield also said that for some VSVP turbines, as the wind speed rose above cut-in but before the turbine had reached rated power, the turbine did reach constant rotor speed. I find that this was part of the common general knowledge albeit that it was unusual. The normal case was as shown in the figure above.

44. A VSVP turbine has two advantages over a constant speed turbine. 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.

45. The second advantage of VSVP machines over constant speed machines is in region III, the region above rated speed. To explain this one needs to have regard to the relationship between generator power, speed and torque which is given by the following equation:

Power = Torque x Speed

46. In a pitch controlled constant speed machine, if the wind speed rises sharply the rotor speed cannot change to accommodate it. In the period before the blade pitch control reacts the aerodynamic torque applied by the wind to the turbine increases. That lasts until the control system causes the blades to be pitched to bring the power and torque back down to rated power and speed. In the meantime the aerodynamic torque, which acts on the rotor, gearbox and generator, has undergone a transient. Accordingly constant speed machines experience significant torque transients.

47. In a VSVP machine, if the wind speed sharply rises, the rotor immediately rotates faster. It is able to do so because it is not synched to the grid frequency. The control system will then react and adjust the pitch of the blades to return rotor speed to the set rotor speed. In the meantime the large heavy rotor has acted like a fly wheel and absorbed the energy of the wind speed transient. The gearbox and generator have not experienced a large increase in torque because most of the aerodynamic torque transient has been applied to speed up the rotor.

48. An issue I need to consider is the extent to which the skilled person was still concerned with torque loads in VSVP turbines but I will return to that in context.

49. Another area relevant to this case relates to turbulence and fatigue. Loads on a turbine are not constant because the wind is turbulent. That turbulence has a natural component but in addition there is also turbulence caused by the blades passing repeatedly through their swept area, within which the wind speed may vary from place to place. This is called rotational sampling. Different parts of the turbine can also be exposed to different and changing loads as a result of turbulence. Operating in high winds requires an increasingly robust structure.

50. Fatigue is a weakening of material caused by cyclic loading on a structure. It is related to both the mean load and the amplitude and number of loading cycles. Turbines are prone to fatiguing due to the combination of large bending moments in the blade and the high number of load cycles. Given the cubic relationship between power and wind speed, turbulence in high winds carries much greater energy than in low winds and this can cause increased fatigue. It is turbulence at high wind speeds which makes a turbine particularly prone to fatigue.

51. In designing a wind turbine the person skilled in the art will have, at the front of his or her mind, the wind conditions in which the turbine may be operating and the dynamic loads to which it may be exposed. A commercial electricity generating turbine represents a major investment. As Mr Butterfield explained, the upside of operating at high, but increasingly rare, wind conditions has to be balanced against the costs of the measures required to make the wind turbine robust enough to cope with the increased loads and fatigue it may experience in its operating life. A point is reached at which the balance often favours shutting down and not exposing the turbine to the dynamic loading which can be associated with such conditions. For this reason a wind turbine might be shut down at a particular wind speed.

52. A point of detail arose relating to the relationship between turbulence/gusts and high wind speeds. It was common ground that with increasing average wind speed the magnitude and the energy of gusts increases (recall that power goes with the cube of wind speed). There was a debate about whether the frequency of gusts increases with higher average wind speeds. Prof Leith's evidence was that the frequency did tend to increase with higher average wind speed. Dr Santos appeared to disagree and produced a plot (RAS 13) based on readings taken from an anemometer on the nacelle on one of the turbines alleged to infringe. However in cross-examination he said it was not his intention to disprove Prof Leith, he did not see the tendency in this data but that did not mean it was not there. I find that the frequency of gusts will increase with average wind speed. This is the case at a qualitative level. No trend was established with any degree of quantitative accuracy.

53. A major dispute concerning common general knowledge related to shut down. There are the following related but distinct points. Did turbines usually (or always) shut down in high wind speeds? If so was there an industry standard shut down speed in 1995 for VSVP turbines? What happened to power and

speed at wind speeds just below the shut down wind speed? What does this tell one about the thinking of the skilled person in 1995?

54. Wobben, supported by Prof Leith, submitted that the common general knowledge was that VSVP turbines were run at constant power and speed up to a shut down wind speed and were shut down at a wind speed which was between 20 and 25 m/s. By 1995 the shut down was typically 25 m/s. Siemens submitted, supported by Mr Butterfield, that while turbines typically did shut down at 25 m/s in 1995, the skilled person also knew as part of their common general knowledge that some did not. Moreover Siemens submitted that "there was no general teaching that speed and power should not be reduced in high wind speeds prior to shut down."

55. There was clear evidence of the existence of turbines which did not shut down at all but these were plainly rare. I find that the skilled person in 1995 would know that such turbines existed in very general terms but regarded them as rare exceptions.

56. As for a value for the shut down speed, in his reply report Mr Butterfield disagreed with Prof Leith's evidence that 25 m/s was the industry standard in 1995 but in cross-examination he used the term "party line" to refer to the 25 m/s shut down speed. Wobben criticised Mr Butterfield for this and it does not reflect well on him that Mr Butterfield had gone out of his way to disagree with "industry standard" in those circumstances. However overall Mr Butterfield's evidence was consistent and did not betray the lack of care alleged by Wobben. He accepted (including in his reply report) that 25 m/s was common in larger machines. His evidence was that there were well known examples of turbines which operated at higher speeds as well as ones which shut down at lower speeds. He gave examples.

57. I should also refer to the text book Hau. It was published in German before the priority date and an English version was published in 2000 which in general reflected the common general knowledge in 1995. The 2000 text referred to a 25 m/s shut down but after Mr Butterfield left the witness box Siemens found the corresponding German text from before the priority date which referred to the range 20-25 m/s instead. Both texts also state that a generally valid criterion to indicate at what wind speed a turbine should shut down does not exist.

58. I find that in 1995 as far as a skilled person considering designing a new large wind turbine was concerned, a shut down wind speed of 25 m/s was the norm. The skilled person would know that exceptions existed but regarded them as such.

59. On the issue of behaviour at wind speeds below shut down speed, Siemens submitted that there was no basis for concluding from various documents exhibited by Prof Leith that it was common general knowledge to continue with rated power and rated rotor speed before shut down. In cross-examination Prof Leith accepted that the documents referred to did not show that but explained that he had not exhibited them for that purpose.

60. In closing Wobben objected to this way of putting the case, arguing that it was not open to Siemens. Wobben pointed out that Mr Butterfield himself had explained how VSVP turbines operated at the priority date and in doing so had explained that in what I have called region III they ran with constant rated power and rated rotor speed. An example is paragraph 77 of his first report.

61. The evidence as a whole establishes that, as a matter of common general knowledge in 1995, the normal way in which a VSVP turbine would be run below the shut down wind speed (and above rated wind speed or power) was with constant rated power and constant rated rotor speed. The fact that the documents referred to which were exhibited to Prof Leith's report may not establish that does not matter because the opinions of the experts support it anyway.

62. Mr Butterfield's evidence also referred to some turbines which ramped down both power and speed in high winds before shutting down. These were stall regulated machines (and some I think which yawed out of the wind). It is also clear that the turbines which behaved this way were largely smaller machines and largely in America but Mr Butterfield did not accept there were no such machines in Europe and did not accept they were only small, non-grid connected, machines. Prof Leith did not know of any such machines in 1995.

63. Wobben suggested that all the evidence relied on by Siemens and Mr Butterfield was from the distant past. I do not agree. A 1994 paper put to Prof Leith in cross-examination from the Risø test facility in Denmark about the variable speed operation of a stall regulated turbine shows rotation speed and power both falling gradually with wind speed as the wind speed rises from 24 m/s. The text includes the statement under the heading "extreme loads" that with the variable speed concept "At very high wind speed, where the contribution to the energy generation is low, the loads (and the power output) might be reduced by reducing the rotational speed."

64. Siemens detected in Wobben's case and possibly in Prof Leith's views, the idea that the skilled person in 1995 considering a VSVP turbine was blinkered in that they would unthinkingly shut down the turbine at 25 m/s and unthinkingly run the turbine at constant speed and power at speeds below shut down. Siemens characterised this as an argument from the patentee based on a prejudice and submitted it was not established.

65. The evidence before me does not establish the existence of anything like a prejudice in the thinking of a skilled person in 1995 in this regard. Taking the shut down speed itself, the fact that shut down at 25 m/s speed was commonly done does not mean that the skilled person was unaware of what the shut down speed represented. The 25 m/s norm in 1995 reflected a balance of factors both economic and technical. Wind speeds of 25 m/s and above are not at all common and the cost of building a machine robust enough to cope with the extra loads and fatigue was not worth the likely economic return of generating extra power. The principal reason for shutting down in extreme winds with a VSVP turbine was to protect the turbine from the effects of dynamic loading and the fatigue this may create.

66. Turning to the operation of a VSVP turbine with constant rated speed and power below shut down speed, that does not equate to a prejudice on the part of the skilled person relevant to their thinking about the effect of high winds and nor does it indicate that the skilled person would be unaware of what would happen if rotor speed was reduced at any given wind speed. Those skilled in the art working in 1995 would not be prompted by their common general knowledge alone to think about operating above shut down wind speed because the norm was to shut down. Nor would their common general knowledge alone prompt them to think about a different way of operating a VSVP turbine in high winds from the normal approach. However I find that a skilled person who was prompted to consider operation above the conventional shut down wind speed would have in mind the aerodynamic forces to which a blade would be subjected (see next paragraph) and would be interested in considering the effect in terms of loading and fatigue on how the turbine was operated at those wind speeds.

67. Part of the skilled person's common general knowledge related to the aerodynamic forces on a rotating turbine blade. 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.

The patent

68. The patent specification is short, consisting of twenty one paragraphs, three figures and four claims. The first paragraph explains that the invention relates to a method of operating a pitch controlled wind turbine. Paragraphs [2] to [8] set out descriptions of dynamic pressure, incident stream velocity and the force acting on the turbine blade. Various equations are provided. It is not in dispute that there is nothing new taught in these paragraphs. Nevertheless its presence in the patent does not indicate that the skilled person has them in mind without prompting in any given circumstances.

69. Reference is made in paragraph [9] to a wind velocity at which turbines are shut down according to the prior art which is denoted V_{wmax}. The Patent then explains a problem in the art:

> "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."

70. Siemens contends this is nothing new. I will address that below in the context of Bossanyi.

71. Paragraph [11] sets out the object of the invention

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

72. The patent then states at paragraph [13] that according to the equations discussed already:

> "… 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 v_u and thus on the operating speed of the rotor."

73. The patent could be read as if this was new information. It is not. The equations were known, as was the idea that the forces acting on the blade are dependent on the incident stream velocity (of which peripheral velocity is the principal component). Nevertheless again, the presence of this information in the patent does not indicate that the skilled person has it in mind without prompting in any given circumstances. The paragraph continues:

> "To limit the load on the rotor of the wind turbine, therefore, when the wind velocity v_w rises or when the incident stream velocity 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."

74. The passage is saying if the incident stream velocity is too large (because the wind speed component is too large), the load can be decreased by reducing rotor speed.

75. In paragraph [14] the inventor proposes:

> "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."

76. This is the concept at the heart of the patent. The idea is to operate at higher wind speeds above the shut down wind speed so as to extend the operating window and potentially increase power yield.

77. Siemens submitted that the following points are of note:

    i) This passage is teaching that according to the invention you operate above a limit velocity at which point "*the wind turbine is* *compulsorily* *reduced in its operating speed*".

    ii) Two potential benefits being advanced are (i) extending the power characteristic at greater wind velocities and improving the power yield and (ii) improving the network compatibility of the wind turbine.

    iii) It is plain that these benefits are available in this way but the passage fails to address the reason why this is beneficial. The inventor fails to provide any technical teaching as to why the increase in yield outweighs the risk and potential fatigue of operating in high winds. It fails to consider the effect that increased dynamic loading will have on components including the blades and the drive train. No load calculations are presented.

78. Points (i) and (ii) are correct. As for (iii), it is true no calculations or further details are provided but there is no argument about plausibility and no relevant allegation of insufficiency.

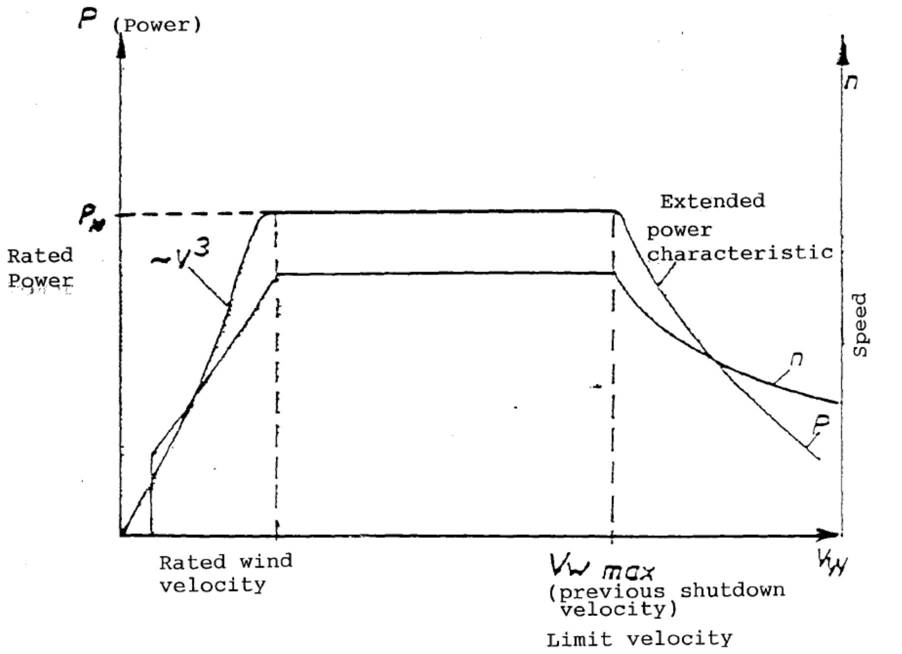
79. Paragraph [14] continues:

> "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."

80. The reference to excessively strong changing and pulsating loads appears to be a reference to the effect of turbulence.

81. Paragraph [15] explains that a reduction in operating speed can be made by use of pitch control which is acknowledged as being known in the art. Paragraph [16] suggests the rotor speed is reduced so that the load level acting on the rotor is approximately constant or is reduced.

82. There are no worked examples in the specification. The single figure of relevance is Figure 1, as follows:



83. This curve is a plot of power and rotor speed against wind speed like Prof Leith's diagrams I have included above. On the left is the region up to the point when rated power is reached. There is a minor and obvious error here where it shows power increasing with wind speed although the rotor is stationary but nothing turns on that. In the middle region the turbine operates in the conventional manner with rated power being maintained and rotor speed being maintained through active pitch control. The difference from the conventional approach comes in relation to shut-down. Instead of shutting down at the point the wind speed reaches a speed labelled V_{wmax}, operation is continued in what is termed the "*extended power characteristic*" with both power and rotor speed being "*continuously*" reduced in dependence on the rise in wind speed.

Claim construction

84. The law is not in dispute. The two key cases are ***Kirin-Amgen Inc v Hoechst Marion Roussel*** [2004] UKHL 46 and ***Virgin Atlantic Airways Ltd v Premium Aircraft Interiors UK Ltd*** [2009] EWCA Civ 1062.

85. While a number of issues of construction appear to arise, I agree with Wobben that this is a case where the issues are better considered in the context in which they arise. The following points are worth mentioning at this point:

i) There is no dispute that in the claims, wind velocity means average wind speed (i.e. the scalar value).

ii) There was a dispute over the meaning of the term wind turbine, but with the amendments in the form of the Main Request that argument disappeared.

iii) The claims refer to the speed of the rotor. In the course of argument and in the evidence, counsel and the experts sometimes refer to generator speed and sometimes to rotor speed. No issue of claim construction arises on the point but it is convenient to mention it here. Owing to gearing and the drive train those two rotation speeds will not necessarily have the same value but in this case they have been used interchangeably without difficulty. In this judgment I use both at different places, reflecting the way the argument and evidence was put.

iv) The claims will cover a turbine which does shut down at a high wind speed. As long as the speed and power are handled appropriately at wind speeds which are in danger of overloading the turbine, shutting down at even higher wind speeds is not excluded.

v) The claim is not limited to using the power and speed reductions only above what one might call a conventional shut down wind speed. The reference to "previous" shut down velocity in figure 3 is just a way of explaining how the invention works. The patent is not concerned only with retrofitting a control strategy to an existing turbine.

Novelty

86. The law on anticipation was set out in ***Synthon v SmithKline Beecham*** [2005] UKHL 59. Anticipation requires an enabling disclosure of subject-matter which, when performed, must necessarily infringe the patented invention.

Novelty – Shozaburo

87. Shozaburo is concerned with the operation of a VSVP wind turbine. It describes a synchronous variable speed generator connected to the grid by an AC-DC-AC converter. The design of the turbine enables both power and rotor speed to be controlled. Siemens contends that this citation and in particular Figure 3 clearly and unambiguously discloses a method of operation which is materially the same as Figure 1 of the patent. It follows that the disclosed method falls within the scope of at least claim 1 of the method claims and the turbine falls within the scope of claim 4.

88. Figure 3 is as follows (with additional notations a, b and c by Siemens in red):

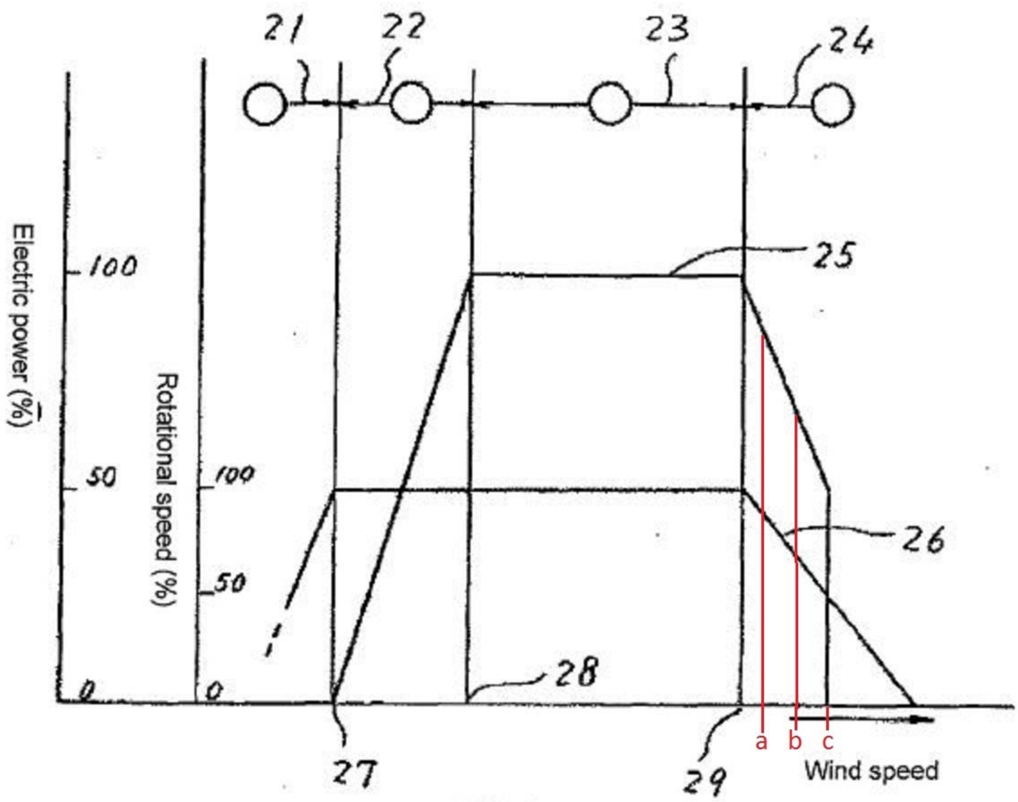


FIG. 3

89. Wind speed is drawn on the x axis and both rotor speed and power are represented on the y axis. Region “22” is the operating region where “rotational speed constant control” is engaged and “23” shows the operating region where “electrical power constant control” is engaged. In region 22 the rotor speed is held constant while power varies as wind speed increases. The rotor speed is controlled by the frequency converter. In region 23 power is held constant and the pitch angle of the blade is changed as wind increases in order to achieve this. Point 27 on the x axis is labelled “cut in”, point 28 is “rated wind speed” and point 29 is “cut out”.

90. On the face of it figure 3 appears to show a continuous reduction in speed and power in dependence upon a rise in wind speed. Siemens added notations “a”, “b” and “c”. As the wind rises from point 29 to “a” a continuous reduction in rotor speed and power seem to be effected. As the wind speed rises from “a” to “b” a further reduction seems to be effected and so forth. Siemens submits that if wind speed drops from “b” back to “a” there will be an increase in rotor speed and power.

91. If this is the correct interpretation of Shozaburo then it is precisely the same as the method disclosed in Figure 1 of the patent. This approach to Shozaburo is supported by Mr Butterfield.

92. Wobben, supported by Prof Leith, does not agree with this interpretation of Shozaburo. Wobben submits that it is vital to read the document as a whole and not simply look at the figure and that, when this is done, the right conclusion is that, despite the reference to wind speed on the x-axis in figure 3, in fact region 24 illustrates the process of shutting down the turbine when

the cut out speed 29 is reached. Although the axis refers to wind speed it is in fact concerned with changes in speed and power over the time during shut down and not behaviour with changing wind speed. Wobben submits that the disclosure of Shozaburo as a whole does not anticipate the patent and that Siemens and Prof Butterfield have fallen into error, in effect by looking at the figure first and then misunderstanding the text.

93. I was initially attracted by Siemens' case in relation to Shozaburo but as the evidence and argument developed I came to the view that Wobben is correct, for the following four reasons.

94. First, one of the principal operating features described in the document is concerned with seeking to hold the rotor speed constant. In paragraph [0005] a problem is described due to changes in the rotational speeds of the turbine and generator. In paragraph [0006] the invention is described as including controlling the rotational speed of the turbine and the generator (NB this alone does not equate to constant speed). In paragraph [0007] there is a summary of how the invention works. It includes keeping the rotational speed constant. There is no reference to changing the prescribed rotational speed. In paragraph [0008] there is a detailed explanation of how the control system works, including references to figure 2. In so far as it relates to rotational speed the paragraph is concerned with bringing rotational speed back to the prescribed speed. If region 24 in figure 3 was concerned with a way of running the turbine in which rotational speed was reduced as wind speed rose above speed 29 and then rotational speed was increased again as wind speed dropped back to speed 29, one might expect to see that discussed in this paragraph. It is absent. In paragraph [0016] the overall operation of the turbine is discussed and again this paragraph refers to maintaining turbine and generator speeds at prescribed speeds. It does not mention a variation in the prescribed speed with wind speed which Siemens' construction of figure 3 would require.

95. Second, while the text in the specification which relates to figure 3 has aspects which can be read either way, on balance I prefer Wobben's construction.

96. The passage related to figure 3 starts at paragraph [0009] and runs to paragraph [0015] or [0016]. I will run through them.

97. Paragraph [0009] contains an express reference to wind speed as the horizontal axis of figure 3. This clearly favours Siemens' interpretation.

98. The start up process is described in paragraphs [0010] and [0011]. Prof Leith read this as referring to what he regarded as the standard way to start a VSVP wind turbine in 1995 which was to hold the rotor stopped until wind speed measured say by an anemometer on the nacelle had reached a level close to cut in. If that is correct then the horizontal axis in figure 3 in this region is not windspeed, it is time and the arrow at the top of figure 3 by number 21 refers to this time dependent start up taking place at cut in windspeed. That in turn supports Wobben's case about region 24 because the arrow at 24 can be construed in the same way and the horizontal axis there regarded as a time dependent shut down not a wind speed dependent control of rotor speed.

99. Siemens challenged this on the facts based on Mr Butterfield's view that another known approach to starting a turbine was to allow it to rotate below the rated speed, effectively using the rotor itself as the tool to measure wind speed. I have accepted that this was part of the common general knowledge in 1995. Siemens also submitted that Prof Leith's view was irrelevant since for novelty purposes the document had to be read as of its date (1981) and Prof Leith was not able to say what was common general knowledge at that time.

100. Siemens' point on dates is correct in law but I do not see that it makes any difference in fact. I am not satisfied that the common general knowledge in 1981 was sufficiently different from the common general knowledge in 1995 to mean that a reader in 1981 would read it differently from a reader in 1995.

101. The language ("When the rotational speed becomes approximately 80% of the rated speed …" and "Next, the circuit breakers … are closed") seems most naturally apt to refer to time but I accept that one can find instances in this art where similar language is used to refer to what happens in similar diagrams as one notionally moves to the right along a horizontal axis which is not time but wind speed. The language in these paragraphs is not clear enough to mandate a construction either way. It certainly does not rule out Wobben's construction. At best for Siemens, paragraphs [0010] and [0011] are neutral.

102. Nothing turns on paragraphs [0012] and [0013]. Paragraph [0012] relates to region 22, above cut-in wind speed 27 and below rated wind speed 28. This is the rotational speed constant control region in which the frequency converter controls the speed. Paragraph [0013] relates to region 23 above rated wind speed 28 and below cut-out wind speed 29. This is the electric power constant control region in which the blade pitch angle controls the speed.

103. Although it does not say so, paragraph [0014] plainly relates to region 24 at least to some extent. It states:

> "Finally, if the wind speed exceeds the operating wind speed, or upon receiving another stop command, the wind turbine initiates feathering, and enters the stop operation. The wind power generator outputs electric power, and suppresses the rising rotational speed at the time of stop, until the wind turbine rotational speed falls to approximately 50% of the rated rotational speed. When the rotational speed falls to approximately 50% as described above, the electric power is considered zero, and the wind power generator is disconnected from the system. In case of an electrical failure of the wind turbine generator, a momentary power disconnection occurs, leading to a stop of the system."

104. The reference to receiving a stop command shows that the paragraph cannot only relate to what happens at or above cut-out wind speed 29 because a stop command could occur for a number of reasons, unrelated to wind speed, such as for maintenance. Thus questions asked in cross-examination which put those parts of the paragraph to one side do not assist.

105. In my judgment the references to "enters the stop operation" and "time of stop" support Wobben. They indicate that what is contemplated is a shut down procedure which, once initiated, runs its course over time. The shut down procedure involves the turbine initiating feathering, i.e. pitching the blades to slow down the rotation. The rotation then slows down to 50% and when this happens the generator is disconnected. The shut down procedure is initiated if the wind speed reaches the cut-out speed 29 or if the turbine receives a stop command.

106. I recognise in Siemens' favour that the reference to "rising rotational speed" seems to fit more naturally with its construction, albeit Wobben contended that it too could be understood in the context of a stop operation. Nevertheless even reading it Siemens' way does not overcome the force of the previous point.

107. There is also apparently temporal language in paragraph [0014] ("When the rotational speed falls … the wind power generator is disconnected…"). That might be the same usage as Siemens contend for in paragraphs [0010] and [0011] but I am bound to say that coupled with "time of stop" I doubt it.

108. Thus overall I find that paragraph [0014] supports Wobben.

109. I wondered if Siemens was taking a point on the fact that paragraph [0015] described each of the four regions 21 to 24 as "operating" regions but counsel confirmed in closing that it was not. The paragraph describes what is going on in region 24 as "the wind turbine is feathering and the power generation control is performed by the frequency converter". This language could be read either way. It is apt to describe both side's approach.

110. I have dealt with [0016] already and the last paragraph of the description, [0017], does not help either way.

111. For these reasons I prefer Wobben's construction of the text.

112. Third, while the x-axis of figure 3 does obviously provide strong support for Siemens' case, there is an important aspect in figure 3 which does not. Wind speed 29 is referred to as "cut-out" and yet Siemens' case is that the turbine does not cut out at that wind speed. On the contrary, according to Siemens the turbine continues to operate above that wind speed and only cuts out at a higher wind speed not labelled in the figure at all. The generator cuts out at unlabelled point c and the rotor rotates (idles) at even higher wind speeds. It only stops turning at the intercept of the rotational speed line with the horizontal axis.

113. Fourth, I was not persuaded that the arrows at the top of figure 3 support either side. They can be understood in a manner consistent with each case. According to Siemens they show that the turbine can move from region to region. So the single arrow at 24 points back to region 23 to show that the turbine's operation can come back into region 23 as wind speed drops back below speed 29. That way all the arrows work the same way. According to Wobben the pairs of arrows on 22 and 23 show the span of those regions while

the single arrows at 21 and 22 show what is happening at cut in speed 27 and cut out speed 29 respectively. Both approaches make sense.

114. Taking the document as a whole, I prefer Wobben's construction to that proposed by Siemens and so I reject the case on lack of novelty. In my judgment when considered carefully the document is not ambiguous. What it discloses to a skilled reader is a system in which the turbine shuts down at the cut out wind speed 29 using a time dependent process depicted in figure 3. That is the disclosure as of its date in 1981. If this document was presented to a skilled person in 1995, the reader would reach the same conclusion and so the invention cannot be obvious over Shozaburo either. To read it as disclosing the approach in the Wobben patent involves hindsight.

Inventive step

115. To be valid an invention must involve an inventive step, which means it must not be obvious to a skilled person having regard to the state of the art (s1(1)(b) and s3 of the 1977 Act, Art 56 EPC). The structured approach to the assessment of obviousness was set out by the Court of Appeal in ***Pozzoli v BDMO*** [2007] EWCA Civ 588. In ***Conor v Angiotech*** [2008] UKHL 49 the House of Lords considered the issue of obviousness. There Lord Hoffmann (with whom the others of their Lordships agreed) approved the following statement of Kitchin J made in ***Generics v Lundbeck*** [2007] RPC 32:

> "The question of obviousness must be considered on the facts of each case. The court must consider the weight to be attached to any particular factor in the light of all the relevant circumstances. These may include such matters as the motive to find a solution to the problem the patent addresses, the number and extent of the possible avenues of research, the effort involved in pursuing them and the expectation of success."

116. In argument Siemens sought to draw an unfavourable comparison between the lack of disclosure supporting the claims in the patent as opposed to the argument about the support for the teaching of the prior art. Without a concomitant invalidity attack based on insufficiency or lack of plausibility, this line of argument is precluded by ***Conor v Angiotech***. For inventive step, what is to be judged is the invention defined in the claim.

117. The skilled person and the common general knowledge have been identified above. There is no need to spend time identifying an inventive concept over and above the words of the claim. The heart of the invention is the concept of running a VSVP turbine in high winds so as to reduce both speed and power in dependence on the rise in wind speed. I will identify the differences between the claim and the prior art in context below.

Bossanyi

118. Bossanyi is a study investigating the frequency of occurrence of sudden large decreases or increases in the power output of potential large wind farms (which it terms "*wind turbine clusters*"). One concern is the impact on the

electricity grid. The author investigates what might happen if a high wind passes through such a cluster causing successive rows of turbines to shut down whereby the grid system experiences a severe ramp down in the total cluster output from full power to zero in a fairly short time. The paper attempts to quantify these effects by estimating the frequency of such an occurrence and then to model how different control strategies might mitigate their impact. The paper proposes various control approaches. The last two sentences of the Summary state:

> "Thus care is needed in selecting the control strategy, and it may be advantageous to use a single centralised control system to control 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."

119. In the paper "furling" means shutting down. The second sentence in the quoted passage is a proposal to replace a shut down at a given high wind speed with a gradual ramping down of power above the conventional shut down wind speed. The proposed gradual ramping down of power is depicted graphically in Figure 3:

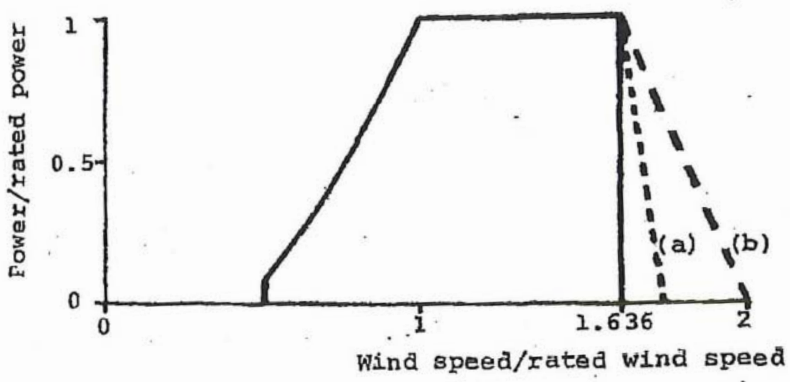


Fig. 3. Normalised Wind Turbine Characteristics

120. The solid line represents the normal control strategy for the particular turbine Bossanyi considers and the dashed lines (a) and (b) represent two possible ramp rates. The turbine actually modelled in Bossanyi is a Mod-2 machine. It is a constant speed turbine with a furling speed of 20.1 m/s. However the figure has been normalised and so the wind speeds are represented by the ratio with the rated speed.

121. Bossanyi obtained real one minute wind speed data from the Meteorological Office and used it to model the behaviour of clusters of turbines in various cases. The base case involves a 20.1m/s furling wind speed and no hysteresis.

In this context applying hysteresis means that once shut down the turbine will not start again until the wind speed has dropped below a level which is lower than the shut down speed by a given amount. This stops the turbine shutting down and starting up too often if the wind speed fluctuates at close to the furling speed. Using hysteresis of this kind is and was a well known technique. Another case modelled uses a furling speed of 17.2 m/s. The paper then models various hysteresis strategies at different furling speeds and finally models the ramp rates (a) and (b).

122. The results of these models are shown in tables, which set out the numbers of ramps in the overall power of the cluster by size, duration and frequency and also the number of furls for each windmill. The word "ramp" in Bossanyi sometimes refers to the overall ramp in power of a cluster and sometimes to the ramp rates (a) and (b) but the context is always clear.

123. The results for ramp rates (a) and (b) are presented in Tables 10 and 11. Since they are based on an original furling speed of 17.2 m/s, Bossanyi compares them to Table 4 (p266, bundle para 29). Results for (a) and (b) were not given for a 20.1 m/s furling speed owing to a lack of sufficiently high wind speeds in the data sample. Bossanyi concludes that while ramp (a) gives only a slight improvement over the sharp cut off case, ramp (b) in figure 3 give "quite a substantial improvement". The paper proposes that the feasibility of this control strategy is worth investigating. The Conclusion section summarises the paper, refers to the possibility of centralising control and ends by stating that if the wind turbine can be controlled to bring power output down gradually to zero at high wind speeds then there are improvements for the individual turbine and also improvements for the cluster by reducing severe power ramps in cluster output.

124. The differences between Bossanyi and the claims are as follows. Claim 1 calls for a reduction in both the power of the turbine and the operating speed of the rotor in the relevant circumstances of high winds whereas Bossanyi only refers to a reduction in power. If claim 1 involves an inventive step over Bossanyi then so will claim 4 and if not, not. Thus there is no need to consider claim 4 separately.

125. Siemens submits that claim 1 is obvious over Bossanyi, relying on Mr Butterfield's evidence. A skilled person given Bossanyi in 1995 would be interested in its reference to the impact on the grid of large reductions in power from wind farms. Although Bossanyi used a constant speed turbine as its model, by 1995 the industry was focussed on VSVP turbines. It would be entirely obvious for the skilled person to consider putting the power ramp proposal into practice in a VSVP turbine. In designing such a turbine they would consider questions of loading and fatigue, all the more so because following Bossanyi the turbine will be running at wind speeds above what would otherwise have been regarded as the shut down wind speed. Loading and fatigue would be a serious concern. In applying Bossanyi to a VSVP machine in 1995 it would be obvious to at least consider reducing rotor speed as well as reducing power in the operation above the usual shut down wind speed because that would obviously reduce loads and fatigue. Running the turbine that way would not involve an inventive step.

126. Wobben argues to the contrary, supported by Prof Leith. First, Wobben emphasises the motivation of the skilled person. The data in Bossanyi does not make a convincing case to do what is proposed at all. The skilled person would not regard the teaching as worth taking forward. Also Wobben contends that the industry was focussed on other issues in 1995 and was not concerned with any issue of cluster power output not least because wind energy was not being generated on a large enough scale to affect the power grid. Moreover even if the skilled person takes Bossanyi forward, Wobben contends that motivation remains a significant issue at all points in the analysis and that motivation is weak. Second Wobben emphasises that the turbine in Bossanyi is a constant speed turbine not a VSVP and the furling speeds (17.2 and 20.1 m/s) are lower than the conventional shut down speed in 1995 (25 m/s). Given the rarity of very high wind speeds, the higher shut down speeds then in use reduce the likelihood of this being a problem even further. Third Wobben contends that even if one considered implementing this in a VSVP turbine in 1995, it was not obvious to reduce rotor speed. In Bossanyi itself the Mod-2 turbine's speed will remain constant even though power is reduced. Moreover when operating both constant speed and VSVP machines above rated wind speed (i.e. in region III, the flat region of Bossanyi figure 3) the skilled person knew that they worked in the same way – with speed kept constant. It was not obvious to reduce rotor speed.

127. In order to decide this issue I will break it down into different topics and address each in turn: motivation, whether to consider a VSVP turbine, how one might implement Bossanyi (including Mr Butterfield's spreadsheets), and whether the skilled person would think of varying speed at all. Then I will consider the matter overall.

Motivation

128. As regards overall motivation, I accept Prof Leith's evidence that the primary focus of the skilled person in 1995 was how to extract maximum power at minimum cost with a reliable turbine, particularly in the light of earlier difficulties with the reliability of turbines which had been experienced in the 1980s. Nevertheless the skilled person was not oblivious to the concern that as wind farms grew larger and contributed a larger share of power to a grid, a simultaneous increase or decrease in power from a cluster such as that caused by a storm front would significantly affect the electricity grid. Mr Butterfield described the rapid growth in wind energy which had taken place in the 1980s and 1990s and which was set to continue. In my judgment the skilled person reading Bossanyi would see the goal of improving network stability relating to wind energy as well worth pursuing.

129. Wobben contends that the skilled person would see that the problem is artificially exaggerated in Bossanyi. The data set did not contain sufficient high winds and could not give results of shut downs at even the Mod-2 turbine's nominal shut down speed of 20.1 m/s. I do not accept that this would reflect the thinking of the skilled person. They would understand that the author had picked a data set in order to model shut down strategies. Clearly given the common general knowledge that the frequency of occurrence of high wind speeds reduces as speed increases, the likelihood of a

shut down reduces as shut down speed rises. The skilled person would see Bossanyi's teaching as a general one that when, for example, a storm front passes through a wind farm, a turbine control strategy involving a gradual ramp down in the power of the individual turbines can help mitigate the risk of the grid experiencing sudden cluster power ramps.

130. I do not accept that much can be made of the fact that the furling speed used to model ramps (a) and (b) was 17.2 m/s. Figure 3 of Bossanyi has been normalised so as to make clear it is not concerned with actual absolute wind speed values. The paper would be of interest to a skilled person thinking of designing a turbine with a nominal shut down speed of 25 m/s or any other shut down speed. Nor do I accept that much turns on the fact that the turbine was a Mod-2. The paper would be understood as a general disclosure.

Whether to consider a VSVP turbine

131. Given the focus on VSVP turbines in the industry in 1995, I am sure that a skilled person given Bossanyi at that time would seriously consider applying its teaching about gradual power reduction to a VSVP turbine. I agree with Siemens that this would be entirely obvious.

How one might implement Bossanyi (including Mr Butterfield's spreadsheets)

132. The next topic to address is how a skilled person would think when considering possible implementation of the gradual power reduction in a VSVP turbine in 1995. Given the relationship between power, speed and torque, one approach would be to produce the downward power ramp with increasing wind speed by reducing generator torque, while pitching the blades enough to cause a matching reduction in aerodynamic torque. That would reduce power while the rotor speed would remain constant. That is the approach which Prof Leith supported (if a skilled person was going to consider this at all). It would not fall within claim 1. Mr Butterfield agreed that the skilled person would know that this was possible but maintained that the skilled person would also know that reducing speed by pitching the blades further and holding the torque constant was also an option. That is another way of reducing power as the wind speed rises but in addition it reduces rotor speed as well. That is within claim 1.

133. Mr Butterfield's view was that this latter option was an obvious one to take given that the skilled person would be considering loads and fatigue. Reducing speed would reduce the aerodynamic force and would reduce static and dynamic loading particularly thrust loading. He said it would be prudent to reduce rotor speed in high winds to provide additional tolerance of turbulence and prevent risk of overspeed. This would reduce costs and extend the life of the turbine.

134. Mr Butterfield produced a spreadsheet calculation which he regarded as the kind of simple analysis of the options which a skilled person would undertake in considering implementation of Bossanyi. The calculations look at thrust loads. They model a reduction in power, deal with the effect of gusts and compare the scenario in which speed is constant and one in which speed is

reduced. Reducing speed as well as power reduces loads considerably. Mr Butterfield's view was that the results supported his opinion that the skilled person would reduce rotor speeds in order to reduce loads on the turbine in high winds.

135. Prof Leith did not accept Mr Butterfield's calculations were realistic for various reasons and produced rival calculations. These were to support Prof Leith's view that Mr Butterfield's calculations greatly exaggerated the loads and were not realistic. Mr Butterfield defended his approach but also emphasised that it was very simple in nature and a skilled person or team designing a turbine in 1995 would carry out a much more detailed analysis.

136. In relation to the calculations I make the following findings:

i) I reject Wobben's submission that Mr Butterfield "did not follow the standard". Mr Butterfield had gone to the IEC 1994 Standard for Wind Turbine Generator Systems (CEI IEC 1400-1: 1994) to obtain a magnitude of gusts. He used a "2 sigma" and a "3.75 sigma" gust. The sigma relates to the frequency of occurrence in terms of standard deviations. A 3.75 sigma gust is likely to occur once a year. In the standard these gusts are associated with a rise time of 6 seconds. In other words the gust of wind is assumed to rise to its peak in that time and falls again in another 6 seconds. However Mr Butterfield was not performing a dynamic calculation but a static one. He was concerned with the magnitude and not the rise time. I accept that this was a reasonable approach in the context of what he was trying to do.

ii) Prof Leith made the point that by modelling the gust in this static manner it was being treated as in effect a wall of wind and the important effect of the turbine's control system was wrongly neglected. In a real turbine the control system would detect an increase in wind speed, react and feather the blade pitch, thus reducing the impact of the gust. Mr Butterfield did not agree that this was a fair criticism given that the rotor takes time to respond and so does the control system. The figures for response times given by Mr Butterfield and Prof Leith were slightly different. Mr Butterfield referred to 3 seconds for the rotor to respond and 1 or 2 seconds for control system to react and so maintained that his approach was totally realistic. Prof Leith gave a period of half to one second for the response time of the control system and did not accept it. Overall I was not convinced the skilled person would be sufficiently sure that the system could respond so fast that Mr Butterfield's approach would be illegitimate as a simple analysis.

iii) Prof Leith pointed out that the ramp rate used in Mr Butterfield's calculations was much more shallow than the ramp rates proposed in Bossanyi and produced revised calculations to show that using ramp rates closer to the actual rates proposed by Bossanyi, the loads were greatly reduced. That follows because using a sharper ramp down rate means that for a given wind speed the power is lower and therefore (at a given generator speed) the torque will be lower. In cross-examination Mr Butterfield could not explain why he had chosen the ramp rate that he had. I am not convinced that the skilled person following Bossanyi would blindly try and replicate the exact ramp rates shown (such as the 3.8 m/s ramp used by Prof Leith) given that Figure 3 has been normalised, however there is force in this criticism of Mr Butterfield and his approach. The ramp rate chosen by Mr Butterfield is much more gradual than the ones in Bossanyi and as an engineer of such experience it must have been obvious to him that this choice would result in showing higher loads than using a steeper ramp rate. The choice of ramp rate ought to have been justified and was not. Nevertheless in the end, as Siemens emphasised, Prof Leith agreed that implementing Bossanyi ramp (b) would lead to an increase in thrust variation, albeit a much smaller one than was shown in Mr Butterfield's spreadsheets.

iv) The calculations include a figure for the resulting angle of attack and lift coefficient in the relevant circumstances. Prof Leith's evidence was that this showed they were unrealistic because the angles were often higher than the angle at which the blade would start to stall. He said it was clear that the blades would be stalled at these angles of attack and that was another "significant flaw" in Mr Butterfield's approach. Mr Butterfield did not agree. Prof Leith's criticism did not take account of dynamic stall which was common general knowledge in 1995 and in which lift is produced at higher angles of attack. Taking that into account meant that in the initial period of the gust the blades would not stall. In cross-examination Prof Leith maintained his view but said it was a relatively minor criticism. In my judgment the stall issue is not a significant flaw in Mr Butterfield's approach at all.

v) Prof Leith pointed out that the calculations were not a fatigue analysis. Mr Butterfield agreed that they were not but maintained that they were to assess on a static basis the effect of a power only ramp down as opposed to a reduction in both power and speed and were well suited for that. I accept Prof Leith's point that the calculations are not a fatigue analysis. I will return to fatigue below.

vi) It is a pity Mr Butterfield did not explain his choice of ramp rate in his report and it is also a pity that Prof Leith's report referred to stall as a "significant flaw". However neither matter is of a magnitude to justify wholesale discounting the evidence of the witness.

137. The spreadsheets also gave rise to a further issue not related to the calculations as such but to a wider point on torque. In replying to Mr Butterfield's spreadsheets Prof Leith said that the power level was more than 4 times rated power which was well beyond what a generator could accommodate. This was in paragraph 38(a) of his second report. The point was to criticise the calculations as producing unrealistically high loads which were "<u>far far</u> higher" than would occur from the gust in the IEC standard (Prof Leith's emphasis). Mr Butterfield explained why this was not right. The point is that the level is a reflection of aerodynamic torque. That aerodynamic torque is not torque experienced by the generator in a VSVP turbine because in such a turbine the rotor speeds up to absorb the gust (the fly wheel effect). The

torque experienced by the drive train and generator is much less. Mr Butterfield's view was that in this context 90% of the aerodynamic torque is absorbed by the rotor and only 10% is passed to the drive train and generator. In a reply report Prof Leith accepted aerodynamic torque does not necessarily reflect the torque experienced by the generator. Siemens submitted that in this respect, although he had corrected it in reply, Prof Leith had initially made a basic mistake which undermined his evidence and showed he was not considering Bossanyi from the point of view of implementing it in a VSVP turbine.

138. Counsel submitted that there was no ground to criticise Prof Leith for this. The Professor had accepted the point made by Mr Butterfield and Counsel submitted that at most the reference to "generator" in paragraph 38(b) should have referred to the rotor, drive train and generator. My difficulty with this is that if Prof Leith had in mind the way in which VSVP turbines operate when he wrote paragraph 38(b) then the text as written would have been misleading. The distinction between the torque acting on the generator and acting on all three elements, including the rotor, is an important one in a VSVP turbine. I do not believe Prof Leith set out to mislead. I conclude that he made an error which reveals that he was not there focussing on how VSVP turbines in particular actually operate.

139. In any case while accepting Mr Butterfield's point, Prof Leith maintained that despite the torque relieving fly wheel effect, residual torque variations would still be a concern. I accept that to a degree but I found Mr Butterfield's evidence on this more persuasive, in that for a VSVP turbine the torque loads make up one of the minor loads whereas concerns about thrust loads at these high wind speeds have more significance. In accepting that I have in mind that it is common ground that peak mean static thrust occurs at the rated wind speed (between region II and III) and not at the shut down wind speed.

140. I have dealt with Mr Butterfield's calculations in detail because they were covered in detail in the evidence at trial but I think it is important not to get distracted by the focus on this issue. It was common general knowledge that turbulence is an increasing problem at high wind speeds. That is why it was conventional to simply shut down turbines at a given high wind speed and the skilled person knew that (I refer back to the common general knowledge above).

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.

Whether the skilled person would think of varying speed at all

142. The real question at this point is whether the skilled person would even consider changing the rotor speed while putting Bossanyi into practice. If they did consider it at all, then 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.

143. Wobben contends that it is only hindsight knowledge of the invention that supports the idea a skilled person would consider this. The idea is a simple one and as such the risk of hindsight infecting the analysis is too easy. I agree that hindsight can be a particular problem with considering inventions based on simple ideas. The fact that the idea is simple does not mean it is obvious.

144. Wobben submits that Mr Butterfield apparently thought nothing of the patent when he first heard of it well before these proceedings but that was after the priority date. It argued that one cannot know if post priority developments mattered and that Mr Butterfield had not been careful to put himself back into the proper mindset in 1995 when giving his opinions. I accept the former point but not the latter. As to the former, I do not propose to place weight on Mr Butterfield's reaction when he first heard of the patent because I am more concerned with an expert's reasons for and against inventive step rather than for the fact they hold a given view. As to the latter, Mr Butterfield's reports showed that he had in mind that the relevant exercise was to consider a notional skilled person, without hindsight, in 1995. I am satisfied his testimony was given on the same basis.

145. Wobben points to the positive way in which Siemens describe their HWRT system, which indicates that it is a real advance. I agree that the literature concerning HWRT is positive and does indicate that the authors regard it as a significant development but I am not persuaded this is of significant weight in relation to the case over Bossanyi, since that item of prior art explicitly discloses the concept of operating above shut down speed and gradually ramping down power to reduce grid problems. The Bossanyi paper was not common general knowledge.

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.

147. The fact that Bossanyi did not reduce rotor speed would not be significant because the skilled person would understand that the particular turbine in the paper was a constant speed turbine but would regard Bossanyi's ideas as just as applicable to a cluster of VSVP machines.

148. The point about resonance would not deter the skilled person from thinking about speed reduction as one of the obvious ways forward. It might ultimately lead to further levels of sophistication in the control strategy but that is all.

149. I do not accept a key part of Wobben's case which involves drawing a parallel between the manner of operation of a constant speed turbine below shut down speed (region III) with the operation of a VSVP turbine in the same region. Wobben argues that speed was constant in region III for both machines and therefore it was not obvious to do anything else above shut down speed. In one sense both kinds of turbine did indeed have a constant speed in region III but really a VSVP turbine has a constant <u>set</u> speed not a constant <u>actual</u> speed (my emphasis). The analogy with constant speed turbines (even ones with an induction generator) loses sight of an important and well known characteristic of VSVP turbines, that in region III the speed varied in order to absorb gusts. Bossanyi proposes to operate the turbine in a manner which was not normal to a skilled person bearing in mind the common general knowledge but Bossanyi also gives a good reason for doing so. The skilled person will naturally consider how to do it.

150. Wobben emphasised that the issue of motivation needs to be kept in mind throughout the analysis over Bossanyi. I accept that in principle but I do not accept it makes any difference in the analysis. Prof Leith did not find the data in Bossanyi to be persuasive and Mr Butterfield agreed it was quite sparse. The data on which it is based is not extensive but nevertheless the paper presents logical conclusions based on the work it describes. The proposal that overall cluster ramp downs which could severely affect the grid may be reduced by making each turbine ramp down its power instead of shutting off makes sense when it is described. Bossanyi's proposal would be of interest and would not be dismissed without careful consideration. Once the skilled person thought about it they would consider how to go about implementing the teaching. The data in the paper and the question of whether grid problems were regarded as a future concern instead of a present one would not alter the skilled person's thinking about implementation.

Overall

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.

152. I conclude that claim 1 is obvious over Bossanyi and so therefore is claim 4.

Infringement

153. The manner in which HWRT works was dealt with in detail in the Product and Process Description (PPD) and was not in dispute.

154. The relevant part of the turbine control system has two systems called handlers which set targets for generator speed and power. They are called the Speed Setpoint Handler and the Power Setpoint Handler. The Speed Setpoint Handler produces a target speed for the generator based on various inputs. Similarly the Power Setpoint Handler uses various inputs to produce a power limit called Active Power Limit. In normal operation the control system works to produce fairly conventional power and speed curves for regions I, II and III. One of the parameters used by the control system is Pitch Reference. That is a value representing the desired pitch angle of the blades so as to achieve a target rotation speed. The pitch control system adjusts the pitch of the blades in accordance with the Pitch Reference.

155. HWRT is a method of reducing both rotation speed and power output in high wind conditions. It is turned on when the wind speed reaches a certain threshold. The wind speed used to determine whether to turn on HWRT is either the 600s, 30s or 1s/1.2s moving average. The lowest turn on speed is a 600s moving average of 23 m/s.

156. In relation to power, when HWRT is on the algorithm continually calculates a filtered moving average of Pitch Reference. A power limit is imposed, based on this moving average, so that the greater the Pitch Reference, the more the power limit is reduced.

157. For rotation speed, when HWRT is on the algorithm continually calculates a value for the filtered moving average of absolute acceleration experienced by the rotor. A speed limit is set by reference to this value. Above a minimum level of the value (a bias level), a reduction in the speed limit is imposed based on the moving average. Above the bias level, the greater the absolute acceleration, the more the speed limit is reduced.

158. There is no real dispute that ignoring rotation speed, the way HWRT controls power is in accordance with claim 1. That is because Pitch Reference is effectively a measure of wind speed and so power is being reduced as wind speed, measured by Pitch Reference, rises. However that is not enough to satisfy the claim because the claim requires both power and speed to be reduced in dependence on the rise in wind speed. I find that considered on its own, the power control method on HWRT satisfies the relevant aspects of the claim. The caveat "on its own" is necessary because in fact power and speed control interact. In the end however the interaction does not matter. If the rotation speed control in HWRT satisfies the relevant parts of the claim then the interaction between speed and power does not avoid infringement. I do not accept anything would turn on the word "continuously" in claim 1 in that case. On the other hand if speed control does not satisfy the claim then the

method does not infringe anyway and the interaction does not give rise to infringement.

159. So far I have mentioned claim 1 only. Claim 4, which is to a product not a method, does not give rise to a separate issue. If the method of HWRT infringes claim 1 then a turbine running it will infringe claim 4 and if not, not. There may be an issue about s60(2) infringement but the parties agreed that that debate can be had, if necessary, on a later occasion.

160. The questions to decide relate to the rotation speed control aspect of HWRT. As mentioned already speed control is performed using an absolute value for rotor acceleration. In more detail this aspect of HWRT is as follows. The relevant part of the PPD (paragraph 83) states as follows:

> "The speed of the rotor (calculated from the generator speed …) at given time points, after being low pass filtered … is numerically differentiated to give <u>rotor acceleration</u> or <u>deceleration</u>. While the most up-to-date measurement of rotational speed (in rpm) is produced [*at shorter, confidential, intervals*], the HWRT algorithm takes samples 200ms apart. The differentiation is done sample to sample, i.e. the difference is calculated between the present reading and the last reading (with a gap between readings of 200ms), and the resulting difference is converted to give rotor acceleration/deceleration in units rpm/s. The absolute value is taken, so that if the acceleration is negative (i.e. a deceleration), the negative sign is disregarded. Consequently a deceleration will have the same effect on HWRT operation as an acceleration of the same magnitude."
>
> (Underlining in the original, ellipsis and [*italics*] are mine to remove confidential details.)

161. The absolute rotor acceleration/deceleration value produced in the passage quoted above is then subjected to a low-pass filter to give a value referred to as the "filtered rotor acceleration". The precise time constant for the filtering is confidential. It is much lower than 600s. The filtered rotor acceleration is subject to the bias. The percentage speed reduction is calculated and the result bounded by 0% to 100%.

162. Siemens contends this does not infringe because the system reduces rotor speed in response to a rotor acceleration or deceleration. This is different from a system based on wind speed because acceleration is the rate of change of speed, in other words the time derivative. As a matter of mathematics, if the only information available is the derivative (the acceleration) one cannot know what the original actual values were. More information would be required.

163. Siemens submits that the wind can be turbulent or blow smoothly. If the wind is blowing at high speed but smoothly then there will be no accelerations or decelerations even though the wind speed is high. The HWRT will not reduce the target speed in that case. Conversely if the wind is at a lower speed but

more turbulent, there will be high accelerations and decelerations. Assuming the changes are above the bias level, the HWRT will reduce the target rotation speed but that would not correspond to a high wind speed. It is true that HWRT is more likely to be working harder at high wind speeds but that is just because, as is well known, the magnitude of gusts, the energy in them and, as I have found, their frequency are greater at high wind speeds. The speed setting by HWRT is based on rates of change in wind speed and not on wind speed itself and thus there can be no infringement.

164. Wobben does not agree. It does not dispute that in simple mathematical terms an acceleration is not a measure of a speed but argues that this case is about a time course of the measurements, which is different. Wobben argues that the evidence shows that in fact the HWRT reduces rotation speed with increasing wind speed and that the evidence shows that in fact this is because filtered rotor acceleration is a measure of the wind speed experienced by the rotor. Thus since a measure of wind speed is being used to control rotation speed in the manner called for by the claim, there is infringement.

165. Each side's case is supported by their expert, Dr Santos for Siemens and Prof Leith for Wobben. Moreover Wobben contends that certain of Siemens' own documents, advanced in evidence under a Civil Evidence Act notice, show that Siemens itself regards filtered rotor acceleration as a measure of wind speed.

Claim construction relevant to infringement

166. I will start by addressing questions of claim construction which relate to infringement. First: whether the claim covers any method of ascertaining wind speed. I do not believe this was really in dispute but in any case the answer is clear. The claim is unspecific and would be satisfied by using any suitable measure of wind speed.

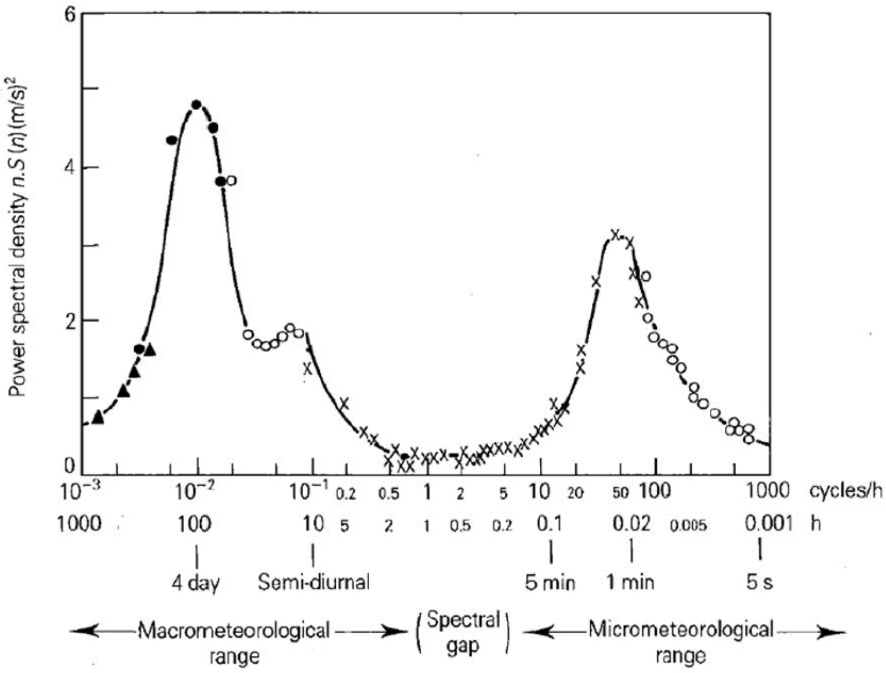
167. Second: "dependent on". The claims calls for a dependency between the reduction in rotor speed and the rise in wind speed. This means that the one must depend upon the other. A coincidental relationship may be evidence from which infringement can be inferred, but to satisfy the claim there has to be a causal relationship between the rotation speed and wind speed. The same goes for power and wind speed.

168. Third: "rise in wind speed". The word rise can be understood in the same context as the dependency. The reduction (in rotor speed or power) depends on the rise (in wind speed). That is all the word rise is getting at. At times it appeared to me that counsel for Wobben was seeking to place some extra emphasis on the word rise which might have seemed to imbue it with significance other than that which I have identified. It sounded like rise might be suggested to have something to do with the word acceleration in the phrase filtered rotor acceleration. But the word acceleration in that phrase refers to acceleration as an absolute value which includes falls (decelerations) just as much as rises (accelerations). Counsel disclaimed any intent to connect references to absolute acceleration with the word rise in the claim. In my

judgment rise bears the meaning I have described and has no other significance.

169. Fourth, whether "wind speed" means a single value or a class of variables. This was how Wobben put its case in closing. At first I did not understand what Wobben meant but I believe what Wobben is getting at is simply that there are different ways of measuring wind speed and the patent is not limited to any particular one. I agree. It is not limited either in the sense of being limited to a technique used to measure wind speed (anemometer, pitch reference etc.) nor is it limited in the sense of requiring any given moving average.

170. In relation to moving averages, a feature of wind is the known existence of a "spectral gap". A graph was produced by Prof Leith from a textbook (Freris):



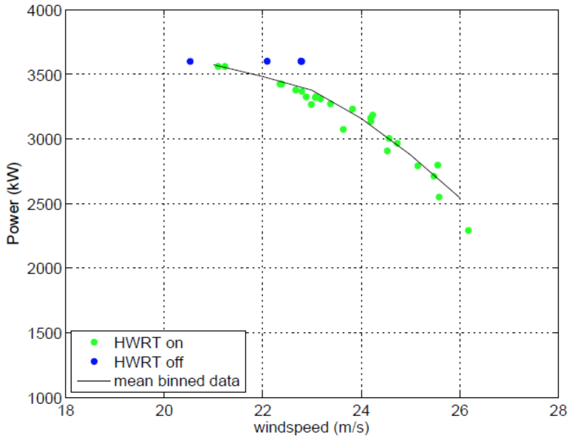
171. This shows the power spectral density of wind plotted against frequency on a logarithmic scale. The peak on the right represents the fact that there is a lot of energy in that high frequency range (peak about 1 minute) while the peak on the left represents variation over a scale of days. The spectral gap is the broad valley between these peaks. Its existence shows that in the wind spectrum, frequency components that have periods between about 10 minutes and 2 hours have very little energy in them. For that reason a 10 minute moving average is an industry standard for measuring wind speed. While that is so, I do not accept that the skilled person would read into the claims a requirement to take a 10 minute moving average wind speed.

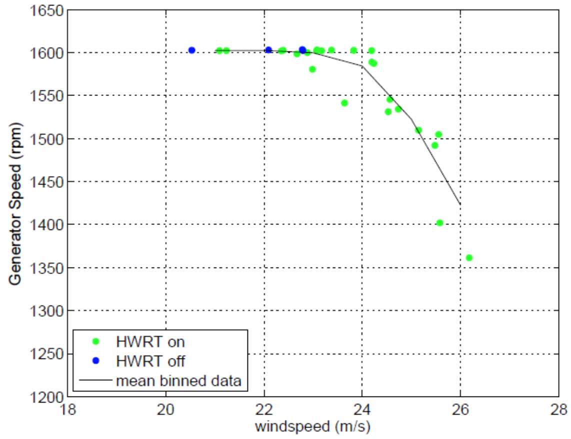
172. Fifth: whether the claim requires power and speed to be dependent on the wind speed measured the same way and averaged over the same timescale. It does not. There is nothing in the claim to exclude a system which uses two different approaches to determining wind speed, one to control power and the

other to control rotor speed, as long as they both are indeed measures of wind speed.

Assessment of Wobben's case on infringement

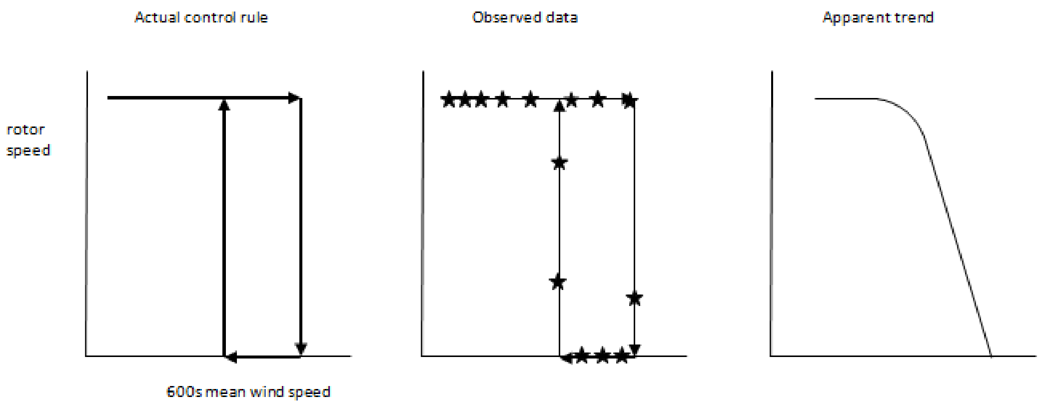
173. The PPD from Siemens included some actual data from the operation of HWRT for turbines in the London Array. In Prof Leith's first report he produced various plots based on that data to support his opinion that Siemens infringes. Two representative plots are these:





174. These plots show generator power (left) and generator speed (right) plotted against wind speed. They are based on averaging and "binning" data, which means putting data together into "bins". The wind speed is a 600s average of the wind speed measured by an anemometer on the nacelle. The relevant dots are the ones for when HWRT is on. They are green (or pale grey in monochrome). On the face of it one can see Wobben's point. Both power and generator speed show a trend of reducing as wind speed rises. There is less scatter on the power plot than the speed plot but Wobben argues that that can be regarded as just noisy data. All the same Prof Leith did not rest his opinion solely on these kinds of plots. While they may show a correlation, he made clear that in consideration of them one needed to understand the actual control relationship [Paragraph 9 of his third report and T2/375 – 376].

175. Before turning to the control relationship, I need to deal with Dr Santos' criticism of these plots and particularly the one related to generator speed. Dr Santos said that averaging and binning was not appropriate to use in these circumstances. He illustrated his point as follows:



176. The left hand shows a notional control relationship, which is a conventional hysteresis approach with shut down at high wind speed but start up at a lower wind speed. The middle is the observed data and the curve on the right shows the result of averaging and binning the data. The curve is misleading. The actual rotor speed is not represented by that curve.

177. Dr Santos was cross-examined on the basis that Prof Leith had not fallen into this error because he had distinguished between HWRT being off and being on using his coloured dots in the representative plots above, however Dr Santos did not agree that this justified Prof Leith's approach. He accepted that Prof Leith had carried out binning in accordance with the way it ought to be done but did not agree that it was appropriate to use at all. Wobben criticised Dr Santos' evidence in this regard, submitting that his criticism of Prof Leith was unfair and was "just wrong".

178. I reject that criticism. The point Dr Santos was making was about the actual behaviour of HWRT when it is on. Dr Santos explained in answer to the questions in cross-examination that most of the time when HWRT is on, the median generator speed does not match the mean. In other words for a lot of the time the set generator speed simply remains at its rated value (in one case 1600 rpm). The speed takes intermittent excursions down to low generator speeds. This pulls the mean generator speed down but as a result the mean speed does not indicate what value the generator speed actually takes at any given time averaged over 10 minutes. Dr Santos described averaging this over 10 minutes as a misuse of the analysis (T3 459 ln24).

179. Dr Santos' point is a persuasive one. It is clear from the PPD that the algorithms in HWRT, in particular the speed setting part, operates over a period of seconds. For example the filtered rotor acceleration value is based on a weighted average in which a significant part of weighting comes from the most recent 15 seconds. In cross-examination Dr Santos estimated that HWRT spends 76% of its time at rated generator speed. Prof Leith was asked if he disputed that HWRT spends most of its time at rated generator speed and said he did not know. I accept the thrust of Dr Santos' evidence. In some periods one can see visually in the dataset provided in the PPD that over a period of 10 minutes (PPD2/annex 5 p63) the speed plot is essentially flat at 1600 rpm save for two excursions down to 1000 rpm each of about 1½ to 2 minutes in length. In this same period the 10 minute average wind speed does

not change appreciably. In other 10 minute periods the plot for the same turbine is more variable and the system there has spent less time at rated rotor speed (e.g. PPD2/annex 5 p65). Whether 76% is representative for all periods does not matter. It is clear that HWRT spends a substantial amount of time at rated generator speed and also clear that the speed reductions can take the form of excursions down and up again over short time scales of tens of seconds or a minute or two.

180. Accordingly I will not place weight on the plots of generator speed against 10 minute average wind speed such as the one included above. 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.

181. The fact that the plot of speed against 600s average wind speed is not representative does not mean that Wobben's infringement case necessarily fails. Prof Leith made clear in his cross-examination that he maintained his opinion that the system infringes despite the point about the amount of time HWRT spends at rated generator speed. However before I deal with that it is convenient to address certain other aspects of Dr Santos' evidence (figures 9 and 11).

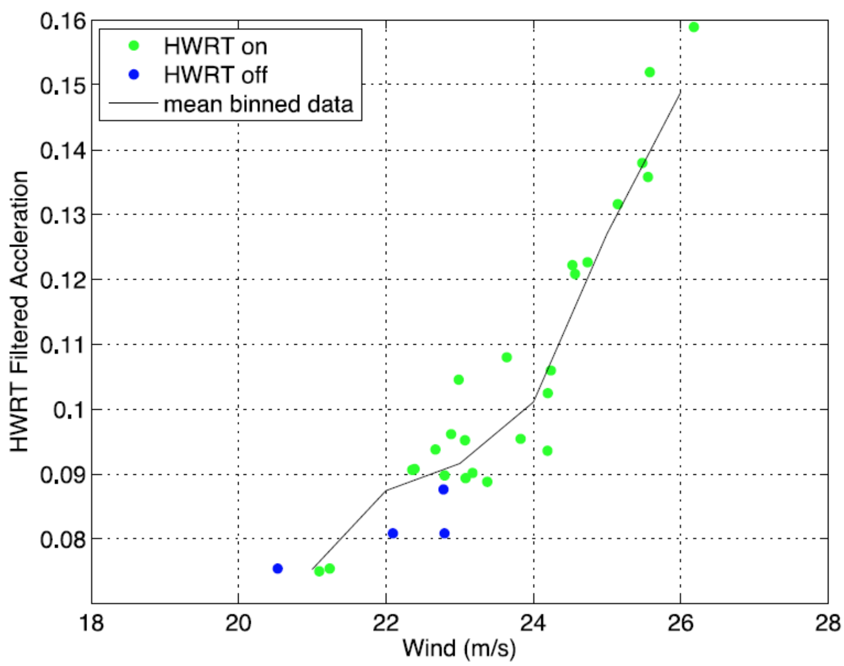
182. Dr Santos had sought in his evidence to demonstrate a related point about the true behaviour of the speed setting in HWRT in figure 9 of his second report. This was a three dimensional plot of the distribution of generator speed reference, 600s wind speed and time spent at a given speed. Prof Leith criticised the way this data had been produced. I will not resolve that issue because I do not believe it is necessary to do so. I did not find figure 9 easy to interpret and I have accepted the thrust of Dr Santos' evidence about the behaviour of the speed setting in HWRT without recourse to figure 9.

183. Dr Santos also produced a plot (figure 11) to show whether the time derivative of rotor speed and the time derivative of power move together. The hypothesis works as follows. Assume that HWRT controls power by reference to wind speed. It follows that if rotor speed is also determined by wind speed, one would expect the derivatives to move together. In other words, if HWRT infringes then as wind speed rises both power and speed would fall while as wind speed falls both power and speed would rise. However the plot shows that power and speed are uncorrelated and so Siemens does not infringe. Prof Leith did not accept that the lack of correlation (which is clear enough looking at the plot) was meaningful. He said that because the plot is based on quantities varying on different timescales, it is not meaningful. There were techniques to do this but they had not been used. Dr Santos's reply to this point was that although the timescales were different, a correlation should still be visible if it existed because in the long run a quantity such as wind speed, even over different time scales should produce the same average. On this I preferred the evidence of Prof Leith. Furthermore if the claim had required power and speed to be dependent on the wind speed measured the same way and averaged over the same timescale then a lack of correlation between power and speed on the same timescale might be persuasive but (a) that is not what the plot purports to show and (b) is not what the claim requires. I will not place weight on figure 11.

184. Prof Leith had another criticism of figure 11 on the basis that taking a derivative of noisy data was inappropriate. Dr Santos agreed that it was inappropriate but did not accept that that is what he had done. In the course of answering Prof Leith Dr Santos produced further plots and in the course of doing this he realised he had made a mistake arising from a misunderstanding of the mathematical software he was using. He corrected the error in a further report. Since I have placed no weight on figure 11 I will not spend a lot of time on this second point. Dr Santos knew not to differentiate noisy data simplistically and did not do so. I was not persuaded by Wobben's attempt to show that the mistake with the der.m function and what Dr Santos thought he was doing demonstrated a material lack of care or undermined any other evidence Dr Santos gave. What the episode did highlight was that there was more working behind the material in Dr Santos' reports. The witness ought to have explained what he had done more fully than he did.

185. Having dealt with these parts of Dr Santos' evidence I can return to Wobben's infringement case. Wobben submits that the properly construed claim does not require use of a 600s average wind speed and therefore not placing weight on Prof Leith's plot based on 600s average wind speed is not determinative because any measure of wind speed will do. Wobben submits the system infringes because filtered rotor acceleration is a measure of wind speed. Putting it another way: since HWRT reduces generator speed in dependence on a rise in filtered rotor acceleration (which is true) the fact that filtered rotor acceleration is a measure of wind speed (if true) means it is also correct to say that HWRT reduces generator speed in dependence on a rise in wind speed.

186. Prof Leith maintained his opinion that filtered rotor acceleration is a measure of wind speed. He produced plots to show the correlation in his report. For example Prof Leith's figure 22 plots the 10 minute mean wind speed measured by an anemometer on the nacelle against a 10 minute mean of the filtered rotor acceleration:



187. Wobben's point is that given this correlation, albeit a noisy one, a skilled person could notionally decide that they were going to measure wind speed by measuring filtered rotor acceleration and reading the wind speed off a graph like the one above. In effect the argument is that if the measured filtered rotor acceleration is about 0.135 then the skilled person would conclude the wind speed was about 25.5 m/s. Equally the argument is that although it may be said that a filtered rotor acceleration of about 0.95 corresponds to a wind speed of anywhere between about 22.5 m/s up to about 24 m/s, all that reflects is the noisy nature of the measurement. Thus filtered rotor acceleration is a measure of wind speed.

188. In closing counsel for Wobben argued in the following way. If one considers the first example mentioned above of a 10 minute period in the dataset provided in the PPD, the fact that the generator speed only changes in two 2 minute periods during that overall 10 minutes is merely because the wind speed, measured by filtered rotor acceleration, has itself only increased above a relevant threshold during those shorter periods. The fact that 600s average wind speed does not change in that period is not relevant. The wind speed measured by different moving averages on scales in minutes down to a few seconds varies considerably. It is the wind speed averaged over a shorter timescale which filtered rotor acceleration is measuring.

189. Counsel's point is inconsistent with the approach based on Prof Leith's figure 22. Counsel's point seeks to grapple with the issue that looking over a 10 minute timescale the median generator speed does not match the mean and seeks to maintain an infringement case despite a finding that the generator speed is not determined by a 10 minute average wind speed. If generator speed is not determined by a 10 minute average wind speed then neither can filtered rotor acceleration be determined by *that* average of wind speed. The point made in closing is an argument that generator speed is determined by a measure of wind speed over a shorter time scale consistent with the 1½ - 2 minute period of the excursion in generator speed. In other words maybe filtered rotor acceleration is a measure of a moving average of wind speed based on a period of more or less one minute. Whether it is or not, this all goes to show that while figure 22 may depict a correlation, it does not demonstrate the existence of a causal relationship between filtered rotor acceleration and 10 minute average wind speed.

190. In my judgment the correlation shown in figure 22 is simply a consequence of the fact, well known to the skilled person, that at higher wind speeds the frequency, magnitude and energy of gusts tends to be greater. I am not persuaded that the noise in the correlation in figure 22 is simply accounted for by the fact that filtered rotor acceleration depends on the wind behaviour experienced by the rotor as a whole whereas the wind speed measurement is by an anemometer on the nacelle and subject to disturbances from the rotor.

191. On the other hand it is important to note that the excursions in generator speed down from the rated speed are not simply determined by a single gust lasting for a few seconds. Counsel's point is related to a point made by Prof Leith in his second report (paragraph 13 of Annex A). Prof Leith explained that the exponential moving average of filtered rotor acceleration has a time constant

which is longer than the time associated with a single gust. The precise time constant number is confidential but it is more than a few seconds. Prof Leith said the following about the reduction in rotor speed:

> "The speed reduction is therefore changed in dependence on the history of gusts and not simply the most recent gust (whether or not that gust is "*transient*"). Therefore the rotor speed will not return to rated rotor speed if the mean wind speed is high and there is a correspondingly high level of continued gusting."

192. This in turn relates to a point made by Prof Leith that while mathematically an acceleration is not the same as a speed, things are more complicated when a time course is taken into account.

193. In the end the question I have to decide is whether filtered rotor acceleration is a measure of wind speed, at any of the relevant time scales. Wobben characterised this as a question of fact, which is true in the sense it is not a matter of law, but it needs to be treated carefully because it can enter the realm of metaphysics. At one place in his reports (2nd report annex A paragraph 11) Prof Leith said that "HWRT uses increases in absolute filtered rotor acceleration as a surrogate for increasing wind speed". This was not intended to be an attempt at anthropomorphism by the Professor.

194. If a quantity correlates with another quantity then measuring one can be treated as a way of measuring the other if that is what the measurer chooses to do. But what if all the person doing the measuring is interested in is the originally measured quantity? Is the fact that it correlates with something else relevant? When a doctor uses a mercury thermometer to measure temperature, he or she is actually measuring the thermal expansion of the metal and relying on the calibration of that expansion to determine the temperature. What is measured is the length of the mercury in the tube but the intention is to measure temperature. As a matter of common sense temperature is being measured because that is how the scale is calibrated and it is how the doctor uses the data.

195. At this point it is convenient to consider Wobben's reliance on documents emanating from Siemens. Wobben contends that these document show that Siemens does indeed regard filtered rotor acceleration as a measure of wind speed and regards HWRT as a system in which speed and power are both reduced in dependence on the rise in wind speed. Given the nature of the argument so far, if Wobben is right then that would be powerful evidence in its favour.

196. First is a scientific paper (Cutululis et al *Impact of High Wind Speed Shut-Down in the Danish Power System* 12th Wind Energy Workshop, London 2013). One of the co-authors is Martin Bjerge of Siemens Wind Power. The paper describes the HWRT system. It produces a power curve (fig 4) which shows power reducing gradually at wind speeds above the normal wind limit. It includes the following two passages:

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

197. Wobben submits this is clearly saying that increasing absolute acceleration is a measure of increasing wind speed, and explaining why that is so. Siemens submits that the second paragraph is entirely accurate in its reference to the fact that it is an increase in wind speed <u>change</u> which results in a speed reduction (my emphasis). In other words it is not an increase in wind speed itself which causes the effect but an increase in the change in wind speed which causes speed reduction. Once the accuracy of the second paragraph is understood and given that the magnitude (etc.) of turbulence is well known to tend to increase with increasing wind speed, Siemens submits that the first paragraph can be seen as simply loose wording. I accept Siemens' point on this paper. Wobben's reliance on it is understandable but properly interpreted, the paper does not support Wobben's case.

198. Second is a set of slides used in 2012 workshop forming part of the EU funded Twenties project in which turbine manufacturers and grid operators worked together. The slides consist of a description of HWRT. They clearly emanate from Siemens. Slide 4 shows a power curve but I cannot draw any material inference from this slide. The key slide is slide 5 (together with slides 8 and 9). Wobben's case is as follows. First, slide 5 explains that a wind sensor is not a reliable source for de-rating because an anemometer is a point measurement and one is interested in a large rotor span. Second, Wobben says that slide 5 then reveals that "wind speed can be predicted from rotor acceleration". Third, that wind speed can be predicted from rotor acceleration is justified by a graph on the bottom left of slide 5 which shows, Wobben submits, that the standard deviation of rotor speed rises with, and is well correlated to, the wind speed. Fourth the point is further justified by later slides 8 and 9. Slide 8 shows very clearly how the variance in wind speed increases as mean wind speed increases (which Wobben states is not a surprising result and consistent with all the expert evidence). The graph on slide 9, top right, shows the standard deviation increasing with increasing mean wind speed; and therefore it too supports the statement that "wind speed can be predicted from rotor acceleration".

199. The issues relating to slide 5 relates to the words and the pictures. First the words. The quotation from the slide is incomplete. The wording on the slide actually reads:

> "Structural loads & wind speed can be predicted from rotor acceleration & pitch angle."

200. Siemens submits that read fairly, the word "respectively" should be understood at the end of the sentence. In other words structural loads can be predicted from rotor acceleration while wind speed can be predicted from pitch angle. Siemens submits that read that way both statements are entirely true and both are consistent with Siemens' case.

201. The second issue relates to the graphs which appear on slide 5 (as well as the later graphs on slides 8 and 9). Wobben is arguing that the graphs support its construction of the words referred to. One problem is that although the graphs on slide 5 have units they are otherwise unlabelled. The writing on the left hand graph is consistent with its being a plot of standard deviation of a rotation speed (rad/sec) against wind speed but that is not stated clearly. Even if that is what that graph has plotted, the logic that what is shown in this graph supports Wobben's case needs to be supported by evidence, but there is none. Prof Leith was not asked to interpret these graphs. When the matter was put to Dr Santos in cross-examination he did not accept what was put to him by counsel. Wobben criticise Dr Santos for straining to avoid what was obvious from the slide. Dr Santos's evidence at this point was argumentative however without evidence from some source, I am not in a position to interpret this material. It is not intuitively clear to me from what I have learned from hearing this case why it follows from the fact that the standard deviation of rotor speed rises with wind speed (assuming that is what the graph shows) that therefore wind speed can be predicted necessarily from rotor acceleration. The timescales are not stated. If Wobben had wanted to make this good it could and should have called evidence from Prof Leith.

202. I do not derive any assistance from slides 8 and 9. Slide 9 is very hard to interpret and slide 8 shows no more than what the skilled person already knows, that the variance in wind speed increases as mean wind speed increases.

203. Considering the slides as a whole, Wobben's way of quoting from the text on slide 5 does not focus on how structural loads are said to be predicted nor on what is said to be predicted from pitch angle. As a matter of words, the tenable constructions of the sentence as a whole are Siemens' "respectively" construction or a construction in which both outputs (loads and wind speed) can be predicted from both or either inputs (rotor acceleration and pitch angle). Whatever the graphs mean they do not shed much light on this. There is no mention of loads in the graphs. Also usually the x–axis on a graph is the input and the y-axis is an output, whereas on Wobben's approach this is reversed. In the end I prefer Siemens' interpretation. It makes technical sense to associate a concern about structural loads with rotor acceleration. It is also completely uncontroversial to predict wind speed from pitch angle. Whatever the correct interpretation of slide 5, it is not clear enough to lend significant weight to Wobben's case. Accordingly neither of the Siemens documents relied on advance the claimant's infringement case.

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.
> [T2/354]

205. The infringement case is pressed not because Prof Leith was wrong in his acceptance of these propositions, but because Wobben's infringement case rests on arguing that the factual premise of those questions was not established. In other words the points put to Prof Leith in the cross-examination quoted above are said to be irrelevant because the proposition that the wind speed could rise in a manner in which there are no increases in gusting or turbulence and no increase in the absolute accelerations measured over the timescales used by HWRT, is wrong as matter of fact. Wobben submits that the evidence in this case of the behaviour of the turbines and the data collected from them shows that the factual proposition is not correct.

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.

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.

208. Finally I will return to how HWRT is operating. In my judgment HWRT is measuring filtered rotor acceleration for its own sake. HWRT reduces 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 is not meaningful to say that HWRT is using filtered rotor acceleration as a surrogate for wind speed.

209. For all these reasons I reject Wobben's case on infringement.

The foreign decisions

210. I will mention these briefly as they were in the trial bundles. Neither side placed reliance on them. The EPO opposition division rejected an opposition by Vestas on 16th January 2003 but they did not have Bossanyi cited to them. In proceedings between Wobben and Siemens AG, the Landgericht Düsseldorf rejected Wobben's claim for infringement. Wobben has appealed and on 15th April 2015 the Oberlandesgericht Düsseldorf has directed that the matter be considered by a court appointed expert. In proceedings between Wobben and Gamesa Corp Technology SA in Spain, the Spanish court has found the patent valid and infringed by certain Gamesa turbines. As I read the Spanish judgment Bossanyi was not cited. It is not clear to me from the judgment whether the Gamesa turbines work in the same way as Siemens' HWRT.

Conclusion

211. The patent is invalid. Even if it was valid it would not be infringed.

Annex 1 - Main Request

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 ~~or incident-stream velocity~~.

2. Method according to Claim 1, characterized in that the operating speed (n) of the rotor is reduced such that the load level acting on the rotor of the wind turbine remains approximately constant or is reduced when the wind velocity rises above the wind velocity which is in danger of producing overloading.

~~3. Method according to Claim 1 or 2, characterized in that the reduction in operating speed is associated with a change in power matched to the load level.~~

4. Wind turbine for the production of electricity in an electrical network with pitch control, characterized by a means for automatic power and rotor-speed reduction when a wind velocity is reached which is in danger of overloading the wind turbine, in dependence on the rise in the wind velocity ~~or incident-stream velocity or the true or relative wind velocity~~.