Power Curve Working Group Agenda

Impact of 'non-standard' inflow

5th Meeting Minutes, Wednesday 4th December 2013, SSE, Glasgow, Scotland

Theme: The 1st meeting gave a clear statement of the problem. The 2nd meeting examined possible solutions. The 3rd meeting put some of those solutions into practice. The 4th meeting consolidated the learning to date by examining new datasets. The 5th meeting focused on validating the candidate correction methods against real data.

Attending: Przemek Marek (Prevailing), Richard Whiting (DNV GL), Andrew Tindal (DNV GL), RV Ahilan (DNV GL), Anna Marsh (DNV GL), Dan Stevens (SSE), Paul Housley (SSE), Gordon Barr (SSE), Peter Stuart (RES), Alex Clerc (RES), Nick Robinson (AWS), Jørgen Højstrup (Romo), Samuel DAVOUST (Avent), Axel Albers (WindGuard), IÑAKI LEZAUN MAS (Gamesa), Tomas Blodau (REPower), David Malins (Scottish Power), Diego Azofra (Barlevento), Michael Pram Nielsen (Vestas), Lasse Svenningsen (EMD), Ralph Torr (Sgurr), Florin Pintille (Sgurr), Ioannis Antoniou (Siemens), Jared Kassebaum (EDF), Will Barker (ZephIR), Mike Hariis (ZephIR), Anabel Gammidge (RWE), Jørgen Højstrup (Højstrup Wind Energy (Romo Wind)), Daniel Marmander (Natural Power), Juha Paldanius (vaisala).

Key Outcomes:

- **Early engagement between turbine suppliers and manufacturers on sites at risk of under-performance (due to non-standard conditions) may help identify mitigations e.g. use of remote sensing measurements and/or conditions specific power curves.**
- **The use of Rotor Equivalent Wind Speed (REWS) in power performance testing may allow for certain contractually defined filters to be relaxed.**
- **The inner-outer range concept is a potentially useful tool in contractually defining performance warranties. The group will publically release a document outlining the Inner-Outer range concept.**
- **The group has achieved a consensus implementation of the Rotor Equivalent Wind Speed (REWS) method. Further work is required to achieve consensus on the turbulence renormalisation method.**
- **Further validation is required to establish the limitations of the REWS and turbulence renormalisation methods e.g. the conditions for which Type B effects become significant.**

Presentations:

- "01 Validation Framework and Dataset 1 Overview" Peter Stuart (RES)
- "02 Rotor Equivalent Wind Speed One Power Curve or Two" Axel Albers (Wind Guard)
- "03 Validation Analysis" Richard Whiting (GLGH)

- “04 Validation Analysis” Alex Clerc (RES)
- “05 Validation Analysis” Jared Kassebaum (EDF)
- “06a - Potential validation Dataset” Daniel Stevens (SSE)
- “06b - Potential validation Dataset” Ralph Torr (Sgurr)
- “07 Proposed Validation Dataset” Peter Stuart (RES)
- “08 Rotor Equivalent Wind Speed and Turbulence Renormalisation Implementation in OpenWind” Nick Robinson (AWS TruePower)
- “09 One year on, A review of Working Group progress to date” Andrew Tindal (GLGH)
- “10 REPower View of Working Group Activities” Tomas Bloadau (REPower)
- “11 Siemens View of Working Group Activities” Ioannis Antoniou (Siemens)
- “12 Vestas View of Working Group Activities” Michael Pram Nielsen (Vestas)

Minutes of Discussion

The group discussed the hypothetical example of a developer who identifies their site as being ‘high risk’ of experiencing performance degradation due to its specific atmospheric conditions. The developer approaches a turbine manufacturer and asks what can be done to ensure that they are given the most accurate power curve for their site.

The turbine manufacturers were asked to comment on what would be the best information for a developer to bring forward in such a situation. One manufacturer said that in their view the most useful information would be remote sensing (tip height) data which would allow the calculation of rotor equivalent wind speed (REWS). The manufacturer said that in their view the use of REWS was the most successful tool in bridging the gap between models and observations.

The manufacturers were asked to comment on whether they would supply a conditions specific power curve in such a situation. The manufacturers present said they had in their experience produced conditions specific power curves at the request of their clients.

The manufacturers were then asked to comment on whether the use of REWS would allow them to relax the filters applied during a power performance test. One manufacturer said that the logic behind the filters in their contracts historically was that conditions like low turbulence were associated with ‘bad profiles’ i.e. where REWS is less than hub wind speed. Another manufacturer added that they would like to avoid the situation where a turbine appears to underperform because hub wind speed is greater than REWS.

One developer commented that in order for them to make the case for going to the extra expense of obtaining remote sensing data the financial benefit of making these measurements must be clear. The developer said that ideally supplying such measurements would lead to a reduction in turbine price (due to the reduction in risk). The manufacturers responded that a reduction in price on this basis was very unlikely, but that the supplying of remote sensing measurements may lead to more favourable warranties (through the removal of filters). One consultant added that it was important that a mechanism was defined so that remote sensing measurement campaigns can be conducted selectively so that costs are not inflated on all projects unnecessarily. Another developer added that the conditions specific power curve may influence the independent engineers estimate by superseding a generic approach with a site/machine specific approach (which may result in a lower loss or uncertainty being assigned).

The group then discussed how to better understand the range of validity of standard and conditions specific power curves. One developer asked the manufacturers to comment on what range of conditions a site specific power curve is representative of i.e. is a conditions specific power curve representative of the full range of site conditions? The developer also asked how should an independent engineer understand a site specific curve e.g. should it be used in place of, or in compliment with, methods such as rotor equivalent wind speed and turbulence renormalisation? The manufacturers responded by saying that conditions specific power curves are much more representative of the average conditions onsite, but may not extend to the full range of experienced on site (see Figure 1 for schematic representation of discussion).

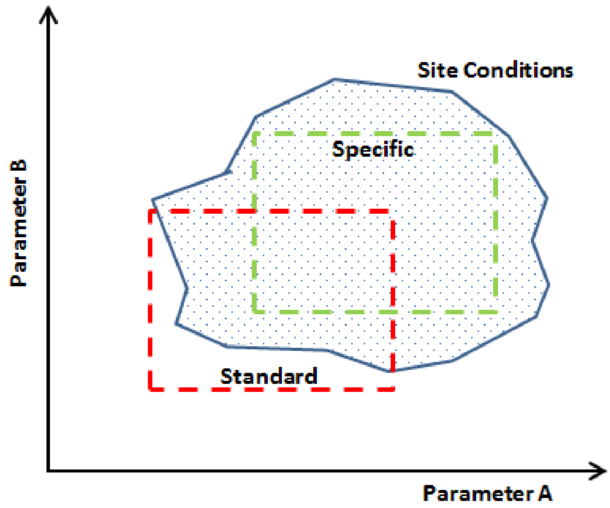

Figure 1. Schematic representation of the range of validity of standard and conditions specific power curves relative to the real site conditions. The conditions specific power curve (green dash) is on the whole more representative of the site conditions (solid blue) than the standard power curve (red dash), however some more extreme site conditions are not well represented by the conditions specific power curve.

One developer stated that they had eight different conditions specific power curves supplied on a particular project (covering different shear and turbulence values). Another developer questioned the consultants as to how they would use site specific power curve information. One consultant responded by saying that a key point is access to a body of evidence which demonstrates the ability of a turbine to meet a stated power curve. The same consultant added that it was essential to understand the starting point when considering corrections to a given power curve i.e. what conditions is a power curve representative of? The consultant said that while it's helpful for manufacturers to clear statement of what conditions a power curve is representative of, ideally a body of evidence would also be made available to demonstrate this performance. The consultant added that if confidence was built up on what corrections should be applied then there would be an adjustment in the uncertainty associated with power curves in resource assessment calculations. One manufacturer responded by saying that it's important not to underestimate how contractual issues may make supplying many separate power curves very difficult, while in contrast the Inner-Outer range concept has the benefit of simplicity and could be used in a contractual context.

Another consultant stated a preference for developers/consultants to focus on predicting turbine conditions and for manufacturers to focus on predicting the power output for these conditions. This was echoed by another consultant who expressed a desire for manufacturers to supply a comprehensive range of power curves covering all relevant conditions. A different consultant commented that current resource assessment practices do not normally differentiate between turbines in how they respond to non-standard conditions.

The group then discussed if it is right for different approaches to be used in a defining contractual warranties and resource assessment calculations. Many of the group thought that there was no compelling reason to force the resource assessment method to be fully consistent with the contract, however others in the group felt that such consistency was important.

Rotor Equivalent Wind Speed Consensus Analysis

The group agreed that the wind speed element of the consensus REWS analysis is now finalised. The group discussed the fact that the current consensus analysis omits the REWS veer term. The group agreed that it would be preference to extend the consensus analysis with veer. The group expressed a preference for a brief round robin exercise on REWS and veer (based on Dataset 3) to be completed ahead of the next meeting.

Turbulence Renormalisation Consensus Analysis

The group agreed that the turbulence renormalisation consensus analysis requires further work before it can be finalised. It was agreed that efforts would be made to make the calculation steps more clear e.g. flow charts. One group member commented that the consensus analysis was mostly fine, but there were some minor issues which should be examined.

Public Distribution of Consensus Analysis

The group was asked if it would be appropriate to publically distribute the consensus analysis. One group member commented that the consensus analysis would need to reference the draft version of the standard on which it is based. Another group member said that it would be very important to state its purpose i.e. to provide a demonstration of how to apply the methods, rather than being an analysis tool.

Manufacturer Supply of Zero Turbulence Power Curve

A few group members raised the question as to whether it would be possible for manufacturers to supply the zero turbulence power curve (instead of having to calculating it from the reference turbulence power curve). One manufacturer commented that the zero turbulence power curve is air density dependent. One consultant said that it would be better to supply a power curve closer to the mean turbulence conditions onsite i.e. the smaller the correction required the more accurate the correction will be (this is also the case with correcting for air density).

Public Release of Inner-Outer Range Concept Document

The group discussed the planned public release of the Inner-Outer Range Concept Document. One consultant said that the Inner-Outer range concept was just one tool in the tool box and did not see any harm in releasing the document. Two developers stated that they were happy to release the document in its current form. A manufacturer commented that the Inner-Outer range concept was a perfectly good way forward for contractual discussions. One group member said they would like some additional time to review the document. The group agreed to remove a statement from the document which suggested it could become an informative annex of the IEC power performance standard. Finally the group agreed to accept comments up until the end of December 2013 with a view to publically releasing the document in January 2014.

Next Step for Validation

The group agreed to work towards a broadening of the existing validation by introducing additional datasets. It was commented that additional datasets should allow performance to be visualised using either 'performance matrices' (as presented by Richard Whiting) or 'error signals' (as presented by Alex Clerc). One group member commented that validation should proceed with both public datasets (data available to the whole group) and proprietary datasets (results shared with the group). Three developers indicated their willingness to source further datasets from within their organisations. One group member said that validation should help the group transition from a mixture of 'player specific' proxy methods towards more generally accepted analytical methods.

Type A vs. Type B

The group discussed the relative impact of Type A effects (available energy) vs. Type B effects (conversion efficiency). The group noted that the current analytical methods tend to calculate relatively small corrections compared to observations (most notably in the low wind speed and low turbulence range). The group discussed some hypothetical sources of Type B effects (e.g. sub-optimal blade pitch during high shear, tip stall etc.), however the group acknowledged the lack of true understanding of the sources of these effects. The group agreed that further validation should help isolate Type A and Type B effects and shed some light on the possible sources of Type B effects. It was agreed that a portion of the next meeting would be dedicated to Type B effects.

Glossary of Terms

The group agreed to develop a glossary of standard terms to assist in communication. Where appropriate the glossary will be consistent with the draft IEC power performance standard.

Public Distribution of Meeting Minutes

The group agreed to continue publically distributing meeting presentations and minutes.

<u>**Summary of Actions**</u>

- **Develop glossary of terms.**
- **Perform round robin exercise for Veer term of REWS method using Dataset 3.**
- **Improve consensus analysis for turbulence renormalisation method making calculation steps clearer e.g. flow charts.**
- **Publically distribute Inner-Outer range concept document.**
- **Identify and distribute additional validation datasets.**
- **Dedicate portion of next meeting to Type B effects.**