

Power Curve Working Group Meeting Minutes

Impact of Outer Range Conditions on Wind Turbine Power Performance
15th Meeting Minutes, Wednesday 9th December 2015, Kings Langley, United Kingdom

Attending: Megan Smith (Carbon Trust), Brian Davison (Sgurr (PHD)), Daniel Marmander (Natural Power), Demetrios Zigras (Nordex), Richard Whiting (Everzone), Michael Pram Nielsen (Vestas), Patrick Hoebeke (3E), Elizabeth Ann Traiger (DNV GL), Stathis Koutoulakos (Vattenfall), Paula Gómez Arranz (DTU), Wiebke Langreder (Wind Solutions), Magnus Davidson (RWE), Matthieu BOQUET (Leosphere), Daniel Stevens (SSE), IÑAKI LEZAUN MAS (Gamesaa), Gemma Allenn (Unkown), Elisa Vega (EON), Graham More (Sgurr), Hector Alonso (Barlovento), Rebeca Rivera Lamata (Dong), Frank Scheurich (Siemens), P.Vorholt@nordex-online.com (Nordex), Nils Schlüter (Wind Consult), Carloalberto Ratti (ZephIR), Muhammad Mangat (ZephIR), John Medley (ZephIR), Scott Eichelberger (Vaisala), Bert Gollnick (Senvion), Raquel Justa (Goldwind), Petros Paterakis (EON), Frank Klintø (Suzlon), Michael Pram Nielsen (Vestas) & Peter Stuart (RES).

Objectives: To review the results of PCWG-Share-01 and define the PCWG 2016 roadmap.

Presentations

- 01 Overview of Results from PCWG-Share-01, Peter Stuart, RES
- 02 Coffee Break Exercise (revisiting the adaptive problem space)
- 03 PCWG 2016 Roadmap & Online Survey Results, Peter Stuart, RES
- 04 3D Matrix Method & Modelling Type B Losses Matthew Colls, Prevailing.
- 05 Advances in the characterisation of the incoming flow using turbine-mounted LIDAR, ZephIR
- 06 Upflow correction presentation, Iñaki Lezaun Mas, Gamesa
- 07 Power Curve Verification: Shear Coefficient and Hub Height Impact, Bert Gollnick, Senvion

Discussions

PCWG-Share-01

The results from the first PCWG intelligence sharing initiative were presented (see presentation '*Overview of Results from PCWG-Share-01*').

It was noted that the aggregated results seem to contain several outlier datasets which need to be investigated. It was noted that additional filters may need to be introduced to clean-up these datasets. The group agreed to reach out to the owners of the outlier datasets to investigate what can be done.

The challenges associated with interpolation were discussed by the group (see presentation '*Overview of Results from PCWG-Share-01*' for background). It was agreed that the group co-ordinator would make contact with the IEC61400-12-1 committee to ascertain what discussions have taken place within IEC61400-12-1 on this issue¹. One working group member suggested that

¹ Subsequent to the PCWG meeting contact was made with the IEC committee who stated that discussions within IEC61400-12-1 had addressed how to present the measured bin-values (defined as the average value within the bin) at the bin-centres. The standard states that the recommended method is to use a cubic spline for interpolation between the bin-values and the bin centre. Although related to challenges experienced within PCWG-Share-01 the historic IEC discussions are considered to address distinct issues.

the use of medians or rolling averages might eliminate the interpolation issues highlighted in the results presentation, however it was noted that the use of such methods would be a departure from the industry standard concepts expressed in IEC61400-12-1.

The group discussed what additional results plots it would like to see. The following amendments were suggested:

- A new plot which separates out control technologies i.e. pitch/stall.
- A new plot which separates out turbine geometries i.e. diameter/hub height.
- A new plot which separates out anemometer types.
- Standard Deviation (by wind speed) should be added to the error by wind speed plots.
- A new plot should be defined which reflects the energy content (this applies to both the 'by wind speed' plots and 'four cell matrix' plots).

One working group member observed some strange behaviour in the mid wind speed range and said that this should be investigated further.

2016 Roadmap Discussion

Following the presentation on the 2016 roadmap survey the group discussed the content of the proposed 2016 PCWG roadmap. One developer asked how many actions the group could take forward in 2016. The co-ordinator responded that the group had bandwidth for 1-2 major actions, but could also address several minor actions.

2016 Roadmap Discussion > Uncertainty Reduction Target

The group discussed whether it was appropriate to set a quantified numeric target for a reduction in uncertainty. One manufacturer commented that it was good to have a target, however it was important not to be blinded by an uncertainty reduction target and keep in mind the key issues e.g. performance dependence on shear and turbulence. One consultant commented that the group needed to set targets that reflected regional cases e.g. the targets should be set such that the methods are right for 90% of cases, not just right on average. Another consultant stated that it was good to set a metric upfront, however it was important to strive for other things that may not be explicitly covered the metric e.g. dependence on upflow, hub height, air density and veer etc. In concluding the group agreed to proceed with a numeric target for uncertainty reduction. The group agreed that a halving of uncertainty relative to the baseline established by PCWG-Share-01 would be a reasonable target.

2016 Roadmap > Inner and Outer Range Considerations

The group discussed whether it was appropriate for the PCWG to take on actions related to both 'Inner Range' and 'Outer Range' performance. The group agreed that it was appropriate for the 2016 PCWG Roadmap to contain actions related to all of the following:

- i. Outer Range Performance Uncertainty**
- ii. Outer Range Performance Corrections**
- iii. Inner Range Performance Uncertainty**
- iv. Inner Range Performance Adjustment Framework**

With respect to item iii) above the members agreed that the Inner Range adjustment framework should be agnostic about the precise numeric values of any adjustment and should instead focus on how stakeholders should make best use of the available information e.g. 'if you have a dataset of 50 historic power performance tests, how best can you use this data to inform likely Inner Range performance'.

A working group member commented that there are well-publicised values in the public domain related to the bias and uncertainty of Inner Range performance and the PCWG should attempt to explain what these numbers mean and what the industry should do with them. Another working group member commented on the misalignment between the uncertainties calculated with IEC 61400-12-1 (power performance standard) and those typically applied in resource assessment industry practice. The same working group member added that the PCWG should 'step into the breach' and address this gap.

2016 Roadmap > PCWG Summary Document

The group discussed the merits of the proposed roadmap action to prepare a summary of the PCWG's activities to date. The group noted the strong support for this proposed action in the roadmap survey and agreed that it would be useful to publically disseminate a summary of the group's activities. One consultant commented that it would be good to put out a PCWG position statement based on the PCWG-Share-01 (intelligence sharing initiative) results, but that perhaps it would be good to expand participation to about 100 datasets before publishing. The co-ordinator suggested that such a position statement could be easily combined with the PCWG summary document. The group co-ordinator also suggested that the release of the summary document could be staggered so that it was initially disseminated as a set of 'interim findings' (with appropriate caveats where necessary) which could be finalised at the end of the year. The group agreed to self-publish an interim summary document at the end of Q1 2016 (summary of all activities to date) and extend this document as actions are completed throughout 2016.

2016 Roadmap > Remote Sensing Data

The group discussed the low volume of remote sensing data in PCWG-Share-01 (4 datasets). The group agreed that the PCWG should push to dramatically increase the volume of remote sensing data in the sharing initiative and that 20 remote sensing datasets would be a good interim target. One working group member noted that it would be important to increase the volume of remote sensing data in order to test the proposed upflow correction (see presentation on this method in the December 2015 PCWG meeting proceedings for more details on the upflow correction).

One working group member expressed concern that existing remote sensing datasets may risk introducing selection bias as often remote sensing devices are only deployed on power performance tests once a problem has been observed using met mast data. A different working group member suggested that it would be useful to examine the consistency of results derived from the remote sensing datasets (using hub height wind speed only) with results from mast based datasets i.e. this should help identify any selection bias introduced by the Remote Sensing datasets.

2016 Roadmap > Harmonisation of Stakeholder Communication

The group discussed the proposed roadmap action related to the harmonisation of stakeholder communication. The group noted the strong support for this action in the roadmap survey. The group agreed that the unfinished 2015 roadmap action to prepare a set of guidelines on how to present turbine performance information should be carried forward into the 2016 roadmap. The group agreed with the principle that the guidelines document should ideally take the form of a checklist. A PCWG and IEC 61400-15 committee member commented that the preparation of these guidelines was compatible with the objectives of the IEC 61400-15 which seeks to define what quantities should be reported (in a resource assessment report).

One working group member said that defining a glossary of terms would be useful as part of preparing the communication guidelines. One IEC 61400-15 committee member stated that a glossary of terms was already being prepared as part of the preparation of the standard. The group co-ordinator agreed to liaise with the IEC 61400-15 to consolidate efforts on preparing a glossary of terms.

2016 Roadmap > IEC Uncertainty Round Robin

The group discussed the roadmap survey question related to the proposal to perform a round robin on the IEC Uncertainty methodology. One developer spoke strongly in favour of performing a round robin on uncertainty (as a 'minor' roadmap action). The group agreed that there was value in performing a round robin, but care should be taken so that the exercise did not become unduly complicated. The group agreed that a round robin on uncertainty should be added as a 2016 roadmap action on the basis that its scope is limited to the Category A components and the Category B wind speed component only. The group agreed that the round robin should be based on the current CDV draft of the IEC 61400-12-1 standard. A straw poll of the meeting participants indicated that at least 8 PCWG members should participate in the uncertainty round robin.

2016 Roadmap > Intelligence Sharing Initiative

The group discussed the inclusion of additional intelligence sharing initiatives as part of the 2016 roadmap. The group agreed that the intelligence sharing initiatives should form a central part of the 2016 roadmap.

The group discussed how the intelligence sharing initiative could be improved. The following issues were raised:

- One member said that care should be taken with respect to the use of turbulence in LiDAR datasets. The member stated that it should be made clear which LiDAR submissions use LiDAR turbulence and which use anemometer turbulence.

- One member stated that care needed to be taken in how results are grouped so that no misleading messages are disseminated.
- The group discussed the number of datasets submitted and agreed that the following should be set as target submission levels:
 - At least 100 datasets in total
 - At least 20 remote sensing datasets.
- The group agreed that the requirement to include shear data should be relaxed so that more datasets could be submitted e.g. nacelle LiDAR datasets.

2016 Roadmap > 3D Power Deviation Matrix & Rotor Wind Speed Ratio

The group discussed the inclusion of the 3D Power Deviation Matrix Method in a future intelligence sharing initiative (e.g. PCWG-Share-02). The group agreed that the dimensions of the candidate 3D matrix should be wind speed, turbulence and a parameter related to vertical wind shear. The group discussed the relative merits of the shear exponent and rotor wind speed ratio parameters (for more detail on these parameters see the presentations '*Power Curve Verification: Shear Coefficient and Hub Height Impact*' and '*3D Matrix Method & Modelling Type B Losses*'). The group agreed that the rotor wind speed ratio parameter is conceptually better suited to the power deviation matrix application than shear exponent.

The group discussed the implications of the group's preference for the Rotor Wind Speed Ratio for the Inner/Outer Range Proposal document. The group noted that the proposal document does not prescribe the use of any particular set of parameters to define the Inner Range. Nonetheless the group agreed that the Inner/Outer range proposal document should be updated to use Rotor Wind Speed Ratio in the illustrative example provided (instead of shear exponent).

One consultant stated that in their opinion the Rotor Wind Speed Ratio should be defined over $\frac{3}{4}$ of the rotor (instead of the full 'tip to tip' distance).

Wind Farm Scale and Wake Flows

The group discussed the proposed roadmap actions related to Outer Range performance at the 'Wind Farm Scale' and in waked flows. The group noted the relative lack of enthusiasm for these actions expressed in the online survey. Some members expressed a concern that addressing the wind farm scale and wake flows in the 2016 roadmap would be attempting to 'run before we can walk'. The group agreed to focus on achievable goals which can be delivered by the end of 2016. In contrast one working group member highlighted the pitfalls of avoiding the 'big picture' (wind farm scale). The group agreed to strike a balance by not defining any 2016 road maps actions related to the wind farm scale and wake flows, however (so that these topics are not completely forgotten) a presentation session will be dedicated to these issues during 2016.

Preparation of the 2016 Roadmap

The group co-ordinator stated that the results of the online survey and the subsequent discussions at the December 2015 PCWG meeting would be used as the basis of a DRAFT 2016 roadmap. Once ready the DRAFT will be circulated to working group members for comment before it is finalised.

Interaction with IEC Discussion

One PCWG member raised a concern that the PCWG could be viewed as interfering with the work of IEC 61400-12-1. Another PCWG member, who is also a member of IEC 61400-12-1, responded that they viewed the PCWG as entirely complimentary to IEC 61400-12-1. The group co-ordinator stated that, based on previous discussions², the PCWG does not view itself as a 'standards orientated group' i.e. it does not seek to create standards itself. The group co-ordinator added that instead of creating standards the PCWG seeks to compliment the work of standards groups (e.g. IEC 61400-12-X and IEC 61400-15) with its own activities. The group agreed that the PCWG should seek to hold a further joint meeting with IEC 61400-12-1 and IEC 61400-15 in 2016.

Proposal for an Online Forum

One group member said that because the PCWG is an 'ideas group', it should consider creating an online forum which members could use to discuss subjects related to the PCWG roadmap. A different member responded by saying that, although they could see merit in the idea, there would be a question over who would moderate such a forum and added that it might be best to trial a forum first before committing to it. Another PCWG member said they thought the forum might help capture ideas, but could become a sprawl and it would be important to avoid random topics.

2016 Meeting Schedule

The group agreed that a total of 6 meetings should be performed in 2016; 4 in Europe and 2 in the US. The European meetings should be evenly spaced throughout the year (one per quarter) and the US meetings should happen within a month of the European meetings. The group agreed that one of the 6 meetings should be a joint meeting with IEC 61400-12 and IEC 61400-15. The group co-ordinator said that he would undertake to define a full calendar of 2016 meetings at the start of the year.

² For previous meeting minutes related to PCWG & IEC Interaction see <http://www.pcwg.org/proceedings/2014-10-06/09-06-October-2014-MoM.pdf> and <http://www.pcwg.org/proceedings/2015-05-08/06%20-%2008%20May%202015%20MoM.pdf>

Group Exercise: Adaptive Problems

During the coffee break the group performed an exercise on adaptive problems based on the work of Heifetz and Linsky (see '02 PCWG 2015 Roadmap - Coffee Break Exercise Result' for details). The group were asked to mark a flip chart with an 'x' to denote where they thought the PCWG stood as a group with respect to the issue of wind turbine performance in outer range conditions. The flip chart was a two-dimensional 'problem space' with political and technical dimensions. The digitised results of the exercise are shown in Figure 4c (2015 results) which indicates that the PCWG members on the whole view the issue of wind turbine performance in outer range conditions as an adaptive problem i.e. far from political certainty and far from technical certainty. For comparison Figure 4b shows the results of an equivalent exercise which was performed in 2014. A comparison of the 2014 and 2015 results suggests that the group has progressed primarily on the political dimension (increased consensus on the need for action) and that much work remains on the technical dimension (consensus on the best way to do things).

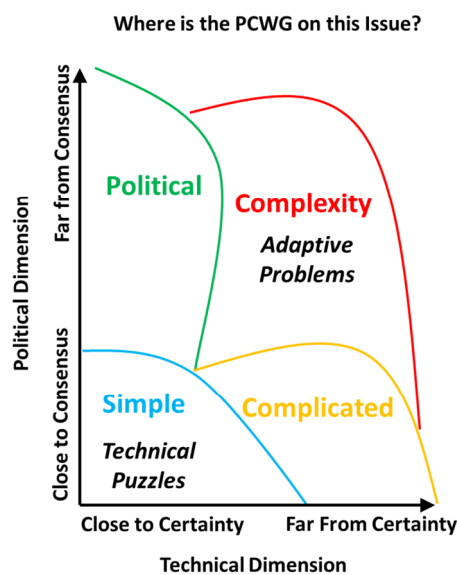


Figure 4a Outline of 'problem space'

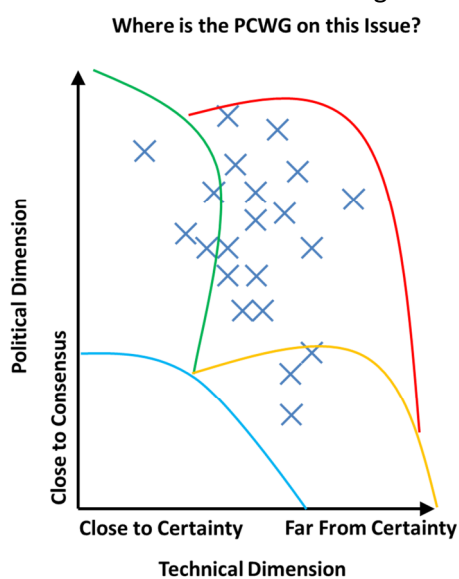


Figure 4b Recorded PCWG member opinions (2014)

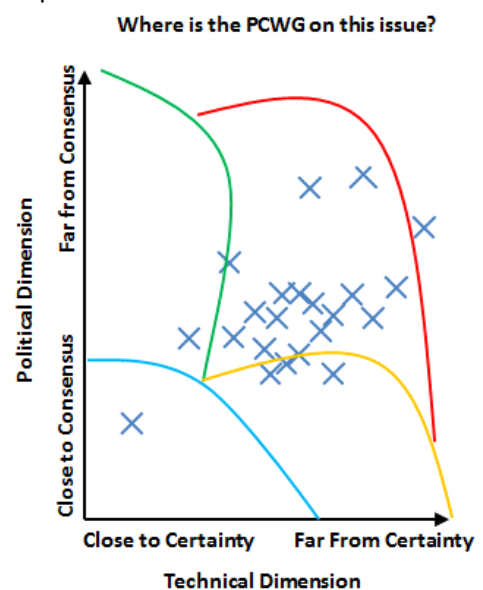


Figure 4c Recorded PCWG member opinions (2015)