Measuring-Network of Wind Energy Institutes

White Paper on Turbulence Intensity Normalization calculations according to IEC 61400-12-1, Edition 2

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1. INTRODUCTION

The MEASNET Expert Group on Power Performance has organised an internal exercise regarding the Turbulence Intensity Normalization according to Annex M of IEC 61400-12-1 (Edition 2, 2017).

The purpose of the exercise was the investigation of different interpretations of the new methodologies among the group members. The investigation constitutes the required step before the formulation of clarification statements which will lead to the harmonization of the interpretation and results.

2. REFERENCE MEASUREMENT PROCEDURE

The Reference Measurement Procedure is:

> *IEC 61400-12-1, Edition 2, 2017-03: Wind energy generation systems- Part 12-1: Power performance measurements of electricity producing wind turbines (Annex M- Normalisation of power curve data according to the turbulence intensity).*

3. ORGANISATION OF THE EXERCISE

3.1 Scope

The scope of the exercise was to compare results of the turbulence intensity normalization methodology as defined in the standard in Annex M.

3.2 Input Datasets

Before delivered to the participants, the datasets were filtered by the data provider to exclude the following conditions:

i. Failure or degradation of test equipment
ii. Wind direction at reference mast outside the valid measurement sector.

The structure of the dataset included the following columns:

1) Date / Time
2) Hub height normalized wind speed (m/s)
3) Active Power (kW)
4) Turbulence intensity

3.3 Required Analysis

The participants were asked to analyse the dataset and to provide their results of the normalized TI according to Annex M.

3.4 Expected Outcome

The items addressed in the exercise can be categorized under the following subjects:

- Two different approaches were proposed in order to identify the differences obtained through each of them in comparison with the calculation efforts:
  - TI normalized power curve obtained through normalization of each 10-min data
  - TI normalized power curve obtained through normalization of the average power for each wind speed bin (after binning of non-normalized power curve)

- Additionally, the participants were requested to provide intermediate results obtained during the different steps through the normalization procedure for an easy identification of the possible misinterpretations and sources of differences.

- Finally, the participants were asked to provide the final TI normalized power curve by following both the methodologies above described:
  - TI normalized power curve obtained through normalization of each 10-min data
  - TI normalized power curve obtained through normalization of the average power for each wind speed bin (after binning of non-normalized power curve)

- The participants were also requested to provide additional information with regards to some considerations during the performance of the calculations (iteration steps, increment size,...) that are not fully defined in the standard, and thus, might lead to some differences on the results.

4. PARTICIPANTS

Ten laboratories participated in the exercise:

- Barlovento (BRN)
- Wind Consult (WICO)
- IWE
- DWG
- TNO
- UL
- DNV-GL
- CEPRI
- Wood
- LME-Circe

5. RESULTS

5.1 Calculation of TI

No deviations among the participants

5.2 Determination of the zero-turbulence power curve

As mentioned, the results through the different steps during obtaining the zero-turbulence power curve were requested to be reported in order to identify possible sources of discrepancy:

5.2.1 Initial zero-turbulence power curve Psim (I=0) initial

- Negligible differences
- "Increment size":
  - No relevant impact on the results is noticed at this step, despite some of the participants having reported 0.001 or 0.01.
- "Correction with residual probability"
  - Some participants declare applying this correction and other do not.
  - No relevant impact on the results is noticed at this step.

5.2.2 First iteration zero-turbulence power curve Psim (I=0) 1st iter.

- Despite slight differences with regards to the inputs at each step (P_rated, Vcut_in,…), negligible differences are observed.

5.2.3 Adjusted zero-turbulence power curve Psim (I=0) adjusted / Number of iterations.

- The same conclusions can be extrapolated.

5.2.4 Final zero-turbulence power curve P (I=0) final.

- Slight differences in input parameters (P_rated, Vcut_in,…) that does not impact the power curve results.

5.3 Turbulence Intensity normalized power curve

- Still some actions must be investigated, as relevant difference arise in this step.

5.4 Turbulence Intensity normalized power curve based on wind speed averaged values instead of 10-min data

- Significant differences are reported between the results of each participant by following the two methodologies.

6. CONCLUSION

6.1 Iteration process for calculation of P(I=0)

Conclusion:

- All parameters shall be updated at each iteration and not only those that meet the convergence criteria.
- Convergence criteria as per the standard (0.5 for Vcut_in)
- "Increment size" seems not to have any relevant impact => however 0.1 as per the standard would be recommended.
- "Vcut_out" causes slight differences => 100 m/s as per the standard should be recommended.
- Stopping the iterations as soon as all the convergence criteria are met.

6.2 Turbulence Intensity Power Curve

Conclusion:

- Calculation based on 10-min data (as per the standard) instead of on averaged power values