Comparison of Production Based Availability Methods

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1. Introduction

Wind farm owners, operators and manufacturers are increasingly focussing on production based availability to assess the performance of their assets. In calculating availability with this approach, it is important to establish a methodology that is fully specified, robust and resilient to instrumentation changes. This brings direct benefits to the financial and contractual management of the asset, as well as supporting the benchmarking of assets across a portfolio.

The IEC Technical Specifications in the 61400-26 series provide an information model that can be adopted by wind farm stakeholders as a common basis for the calculation of availability. 61400-26-1 provides an information model for time-weighted availability and 61400-26-2 extends this to production-based availability. This provides a framework for establishing the energy shortfall resulting when a wind turbine is non-operative as well as when a turbine is not in full performance (e.g. being de-rated).

A key step in calculating production-based availability is the derivation of potential energy i.e. the energy that would have been produced given the wind resource were the asset under consideration operating at full performance. Under the IEC framework, some high level guidelines are given to calculate the expected energy, with several possible methods defined.

Owners, operators and OEMs have to make a decision about which method is most appropriate and in which circumstances should each method be deployed. To help address this question, the authors have investigated the difference between the methods when applied to a number of operational wind farm data sets.

2. Approach

Methodologies to estimate the expected energy at a given turbine in IEC 61400-26-2 are divided into two categories. These two categories are further divided, giving a total of 7 methods:

1. Power-based methodologies that use neighbouring turbine power or site average power of turbine in full performance (methods P1 & P2); and
2. Wind speed and reference power curve methodologies (methods W1 – W5).

The authors have undertaken a study to compare the methods; ten operational wind farm SCADA datasets were defined and the methods applied on each. The datasets were from both onshore and offshore wind farms. For each wind farm, the methodologies (W1 to W5) have been used calculate:

1. The expected power; and
2. The ratio of the expected power to the actual power.

The authors have carefully considered the implementation of each methodology at hand including the applicability as a function of operational circumstances e.g. turbine downtime, site curtailment, loss of SCADA data, etc. Practical considerations regarding the implementation of the methods will be described in the paper. In addition to considerations of the accuracy of each method there is a difference in the effort of implementation, therefore the final choice of method may not be a completely technical decision.

Based on the above approach, a set of criteria have been established for comparing the methodologies between themselves, as detailed in Table 1.

Criterion	Measurement
Accuracy and precision	Quantitative comparison of the expected energy against the actual energy when the turbines are operating in full performance.
Uncertainty	The coverage of the methodology i.e. the proportion of data points over which a given methodology is applicable over the total number of data points considered.
Complexity	A qualitative comment on the effort or analytical overhead required to implement each method.

Table 1. Production-based availability methodology assessment criteria.

3. Results

3.1 Accuracy and Precision

The following metrics have been calculated for each method:

1. The mean ratio of the expected power to the actual power;
2. The standard deviation of the expected power to the actual power.

Figure 1 gives an example result, showing the mean error across one site on a monthly basis for each of the seven methods. From this chart, it can be seen that the there is significant variation between the methods. Within each method, there is also variation from month to month, resulting from differences in operational conditions. The month to month variation is quantified with the standard deviation metric. In general, wind speed-based method W5 gives the highest error between expected and actual power, whereas the production methods give the lowest variation.

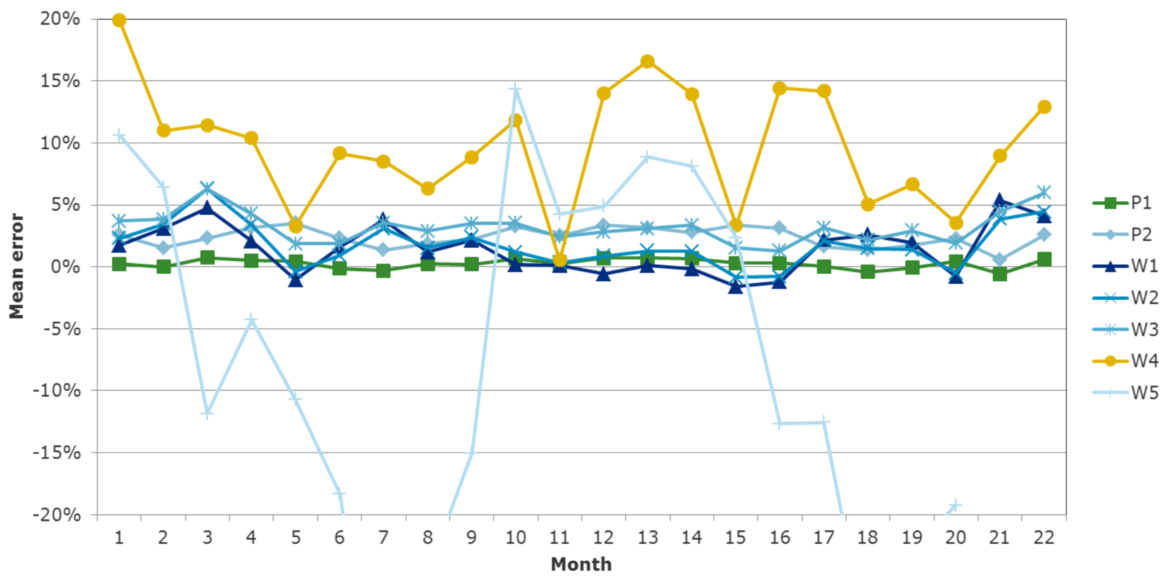

Figure 1. Example result showing mean error across the site on a monthly basis for the 7 different methods.

This is further illustrated in Figure 2, which shows the root mean square error across all months for each of the different methods. From this chart, it can clearly be seen that method P1 gives the lowest overall error.

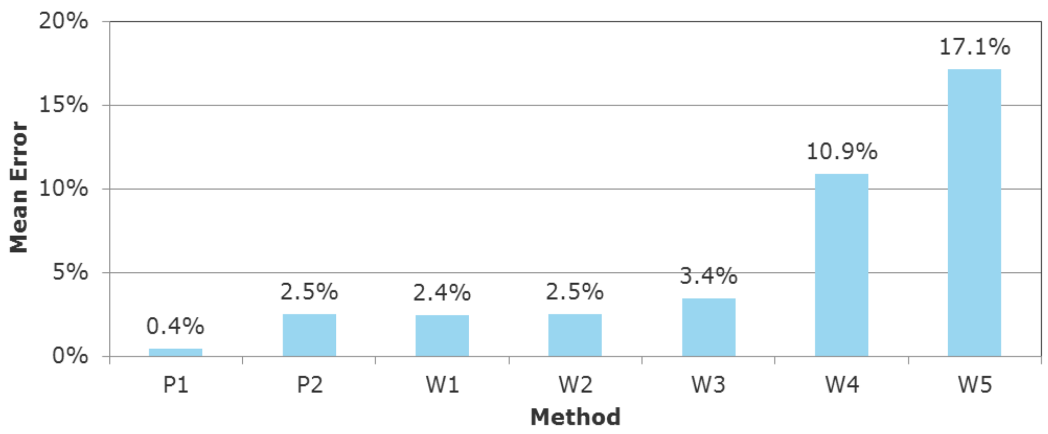

Figure 2. Example result showing root mean square error for the 7 different methods.

3.2 Uncertainty

The uncertainty associated with each methodology has been quantified in terms of the coverage of the methodology. This is calculated as the proportion of data points over which a given methodology is applicable over the total number of data points considered. Where there are fewer data points calculated with a given methodology, there is greater uncertainty in the total expected power. The results are presented in the full paper.

3.3 Complexity

Based on the experience of implementing each method, the authors will give a qualitative comment on the effort and analytical overhead required to implement each method.

3.4 Special considerations for wind speed methods

When assessing the wind speed based methodologies (W1 to W5) consistent anemometer wind speed readings are required. Therefore the methods rely on the wind speed measurement for turbine in full performance being consistent with wind speed measurement for turbine not in full performance. In order to validate this assumption, the authors have:

1. Derived a signal that is the nacelle anemometer wind speed average for turbines in full operation;
2. Derived a signal that is the nacelle anemometer wind speed average for turbines not in full operation;
3. Correlated the 2 signals on a time basis.

It is concluded that the suitability of this assumption is turbine type dependent, being affected by blade root geometry, anemometer type and location, etc.

3.5 Onshore versus offshore

Considerations between applicability of methodology to onshore and offshore projects will be considered in the paper. The authors conclude that a straight application of a methodology suited to an onshore site often associated with complex topography and forestry may not be either the most cost effective or the most accurate approach to the derivation of expected energy and production based availability. Results comparing the errors calculated when applying each method to the onshore and offshore site will be given and commented upon.

3.6 Choice of method

Based on the results, a decision tree indicating which methodology is applicable and best suited for a given operational scenario has been made, as shown in Figure 2. This allows the reader to gauge the expected level of accuracy for a given operational scenario.

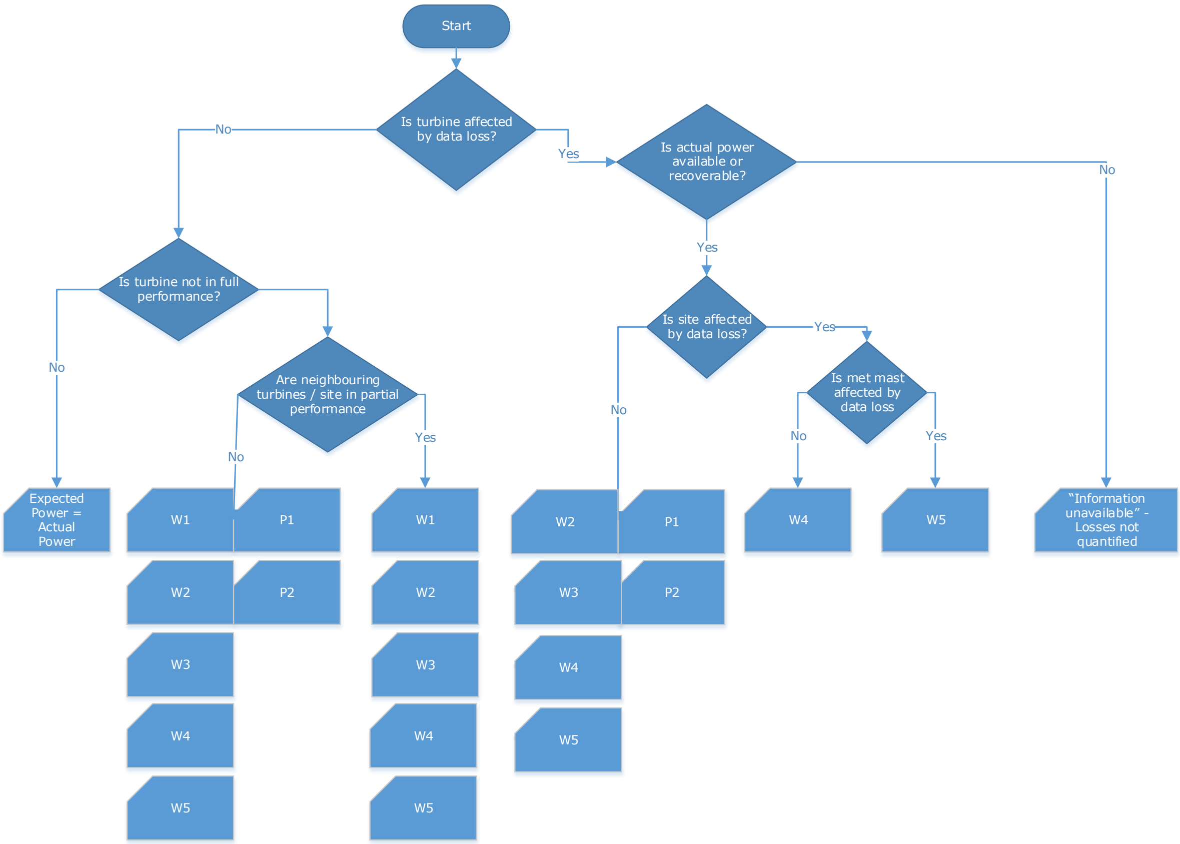

Figure 2. Production-based availability methodology decision tree.

4. Conclusions

The 7 different methods for calculating availability described in IEC 61400-26-2 have been applied to 10 operational wind farm SCADA data sets. The authors draw the following conclusions:

1. Production methods have the lowest error, in general.
2. Wind speed-based methods incur an additional penalty of complexity of implementation and do not yield more accurate results.
3. Application of a methodology suited to an onshore site often associated with complex topography and forestry may be neither the most cost effective nor the most accurate approach to the derivation of expected energy and production based availability.
4. The suitability of wind speed methods is turbine type dependent, being affected by blade root geometry, anemometer type and location, etc.

5. Learning objectives

Learning objectives from the work include an understanding of:

1. The different production-based availability methodologies provided in IEC 61400-26-2;
2. A description of a methodology for comparison of production-based availability;
3. A quantitative comparison of the different methods;
4. An approach to make an informed decision about which method to apply to which wind farms.