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Methods for long-term correction in a post-construction energy yield analysis

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Abstract and Objectives

Post-construction energy yield analyses are useful for re-financing and when a wind farm is going to be sold. The total uncertainty in a post-construction yield analysis is typically half of that in a pre-construction yield analysis [1]. The long-term adjustment of the measured power is one of the major tasks in the post-construction yield analysis. There are different methods available to do the long-term adjustment and the most suitable method depends on the quality of the operational data. The results based on four methods from two wind farms have been compared. The wind farms are located in areas affected by icing during the cold part of the year. This will cause a seasonal dependence in the data availability that is affecting the results. This also mean that some of the conclusions drawn might be valid mainly for wind farms were icing occur regularly.

It is important to select the most proper method(s) in a post-construction energy yield analysis. The uncertainty in the long-term correction depends on the length of the operational period and by the used methods. By calculating the annual energy production (AEP) for different operational periods using several methods it is possible to estimate this uncertainty.

The long-term adjustment methods used in this analysis can be divided into two different categories, "Historical power curve methods" (HPCM) and "Index methods" (IM). Common for all methods is that only data from when turbines are operating in full-performance should be used. Full-performance is defined as "The WTGS is operative and generating according to design specifications with no technical restrictions or limitations which affect generation." [2].

Historical Power Curve Methods

HPCM are using turbine specific power curves (PCs) derived from measured power in combination with the nacelle wind speed or modeled data. The specific PCs are used with long-term time series of wind speed to calculate time series of production from which production statistics can be calculated.

It is important to use a sufficiently long time period for the PC to be well defined and at the same time short enough to avoid operational changes made to the turbine. Figure 1 show PCs from one turbine based on wind from the nacelle anemometer and measured production from different periods. A change made to the turbine anemometry is responsible for the difference in the PC.

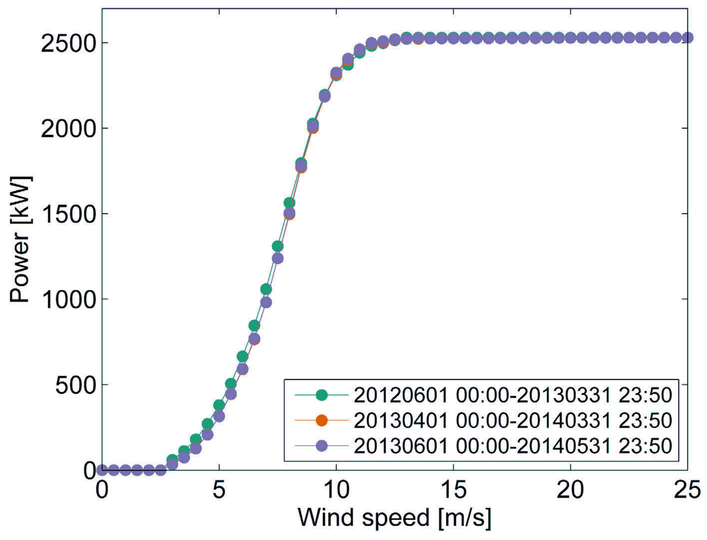

Figure 1. Example of PCs based on nacelle anemometer wind speed and measured production from different time periods. The maximum difference between the PCs from different time periods is 7 % at around 7 m/s.

Index Methods

The IM are relating the measured power to either a wind index or a production index. The measured power must be adjusted so that it corresponds to an availability of 100 %. The index is typically constructed on a monthly basis, but since considerable uncertainty is associated with the availability correction, it can sometimes be more strategic to construct the index on a weekly basis. In Figure 2 a production index versus availability corrected weekly production is shown, only weeks with an availability larger than 95 % is included in the regression. A linear relationship relating the index and the production is shown by the red line. The expected weekly normal production is found at index 100. The WRAEP can be calculated from

WRAEP = 52.18 x "Expected normal weekly prod"

The methodology is the same for IMs based on monthly periods, with the difference that WRAEP is calculated as 12 x "Expected normal monthly prod".

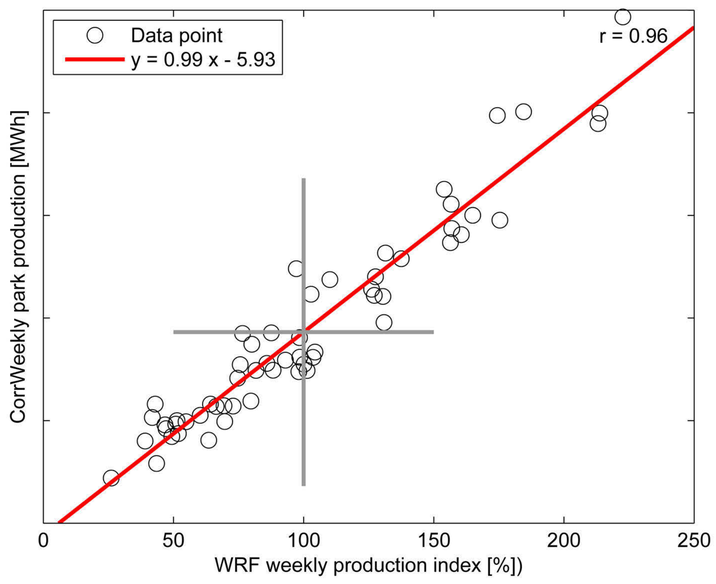

Figure 2. Example of a weekly production index based on model data vs. weekly production corrected for availability. Only weeks with availability > 95% are included in the regression.

Figure 2 shows the sensitivity in the long-term estimate of the AEP when using months/weeks with different requirements on the data availability.

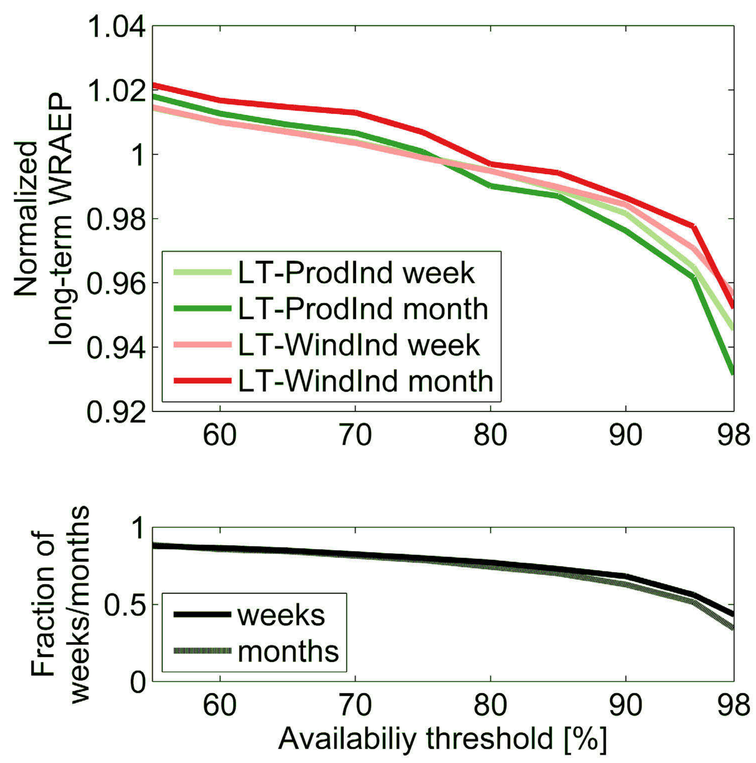

Figure 3. The sensitivity in the long-term wake reduced AEP (WRAEP) estimate with respect to the availability threshold of the months/weeks used in the regression of the different methods. LT-ProdInd week/month are IM methods using a production index and LT-WindInd week/month are IM methods using a wind index.

Results and Conclusions

The sensitivity of the post-construction production estimate with respect to the length of the operational period is found in Figure 4. It is seen that the difference in the methods stabilize after 36 months. After that there is a constant inter-spread of about 4 %, which is an indication of the method uncertainty. The wave like appearance is due to seasonal effects.

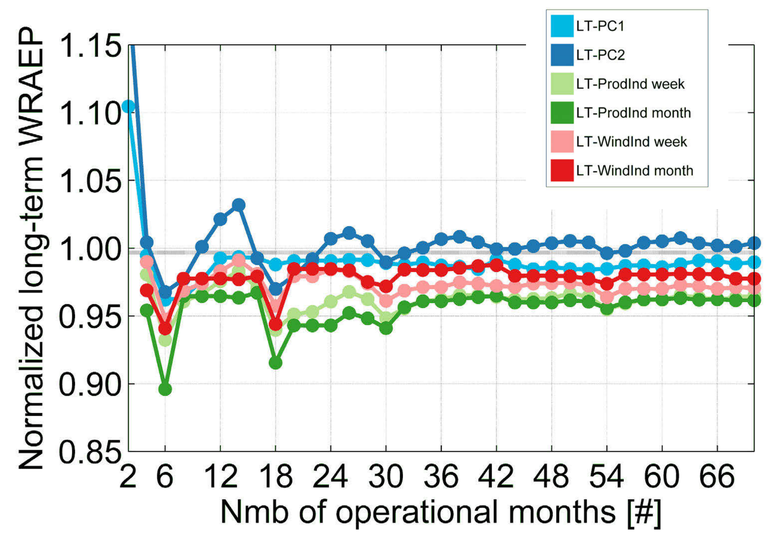

Figure 4. Sensitivity of the WRAEP with respect to the length of the operational period. The blue lines are estimates based on HPCM methods and green/red lines are based on IM methods.

HPCM based on measured wind speed is suitable if the nacelle anemometer is consistent during the operational period and also for short (six months to one year) operational periods provided that the turbines are operating in full-performance during the majority of the time. HPCM with modeled wind speed is suitable to use if the nacelle anemometer is inconsistent, making it difficult to create valid turbine specific power curves. But using modeled wind speed require longer operational period to properly define sector wise power curves. The IMs are typically good to use if the nacelle anemometer is inconsistent. And by using both weekly and monthly index periods, it is possible to get additional estimates of the AEP for uncertainty assessments. The suitability of the methods are summarized in Table 1.

Table 1. Summary of when the different methods to long-term correct operational data is recommended.

		HPCM Measured wind	HPCM Modeled wind	IM Prod/Wind
Recommended if	Short operational period	Yes	No	No, but weekly basis better
	Long operational period but large amount of non-full performance periods.	Yes	Yes	No
	Inconsistencies in the nacelle anemometer	No	Yes	Yes

References

1. Post-construction production assessment of wind farms, Assessment and optimization of the energy production of operational wind farms: Part 1, Energiforsk report 2016:297, ISBN 978-91-7673-297-7, www.energiforsk.se
2. IEC TS 61400-26-1: Time based availability for wind turbines, *International Electrotechnical Commission*