Vaisala 3TIER Services COVENANT Process:

Methods Validation Update Report

Methods Change

Wake Model and Loss Structure Updates

DATE

29 January, 2020

CONTACT

ph: +1 206.325.1573
2001 6th Avenue, Suite 2100
Seattle, WA 98121
www.vaisala.com/energy

VAISALA

Process Versioning	
Most Recent Validated Version	8.0
Process Updates Version	9.0

Disclaimer

Contents

1 PROCESS BACKGROUND

In 2015, Vaisala conducted a significant validation study [1] of its due diligence wind energy assessment methodology. The study was based on 127 years of energy from commercial operations at 30 different wind farms in the United States, Europe, and Asia. Pre-construction assessments were performed with Vaisala's current methodology in a blind retrospective forecast framework. This validation, which demonstrated calibration of methods, was the basis for broad industry acceptance of Vaisala's methods.

Since the December 2015 release of our wind energy assessment validation paper, we have continued to evolve our methodology. Today, Vaisala uses a ground-breaking continuous validation process as a bridge between the need for both innovation and stability. This approach provides an ongoing view into how we are performing, so that we can innovate while at the same time monitor the effects and benefits of each innovation to guard against sudden shifts in accuracy.

In essence, each time a proposed innovation is introduced, a standard test suite is set up, which is designed to completely recreate the energy estimates used in our original validation study. Once the test suite is executed, the results are analyzed to evaluate the corresponding impact on errors and uncertainty. The process effectively tests the innovation against our entire validation database.

If sudden changes in our error or uncertainty values are uncovered during our testing process, either we investigate and address the cause as a result of the new innovation or it is simply not implemented. If the final results show a decreased uncertainty, with no significant change in mean bias error, the result demonstrates that the innovation is a genuine improvement, and it is incorporated into our methodology. By following this approach and showing transparency, we maintain stakeholders' confidence in our process while incrementally benefiting from new innovation and the improved results it delivers to our clients. This methodology evaluation is known as Vaisala's COVENANT process (COntinuous Validation of ENergy AssessmeNT).

Vaisala's most recently validated version of our methods, prior to the currently proposed new version, is Version 8.0. This Version 8.0 showed mean bias error for all wind farm years (where "error" is defined as actual energy produced minus the pre-construction long-term estimate, expressed as a percent) was -0.34%, with a 95% confidence interval of +/- 4.3%. The standard deviation of the 1-year errors was 8.42%, somewhat lower than Vaisala's mean estimated 1-year uncertainty on energy of 11.28%, indicating that Vaisala's estimated uncertainties have been somewhat conservative.

2 OVERVIEW OF CURRENT UPDATES

This section describes the method change(s) that were tested for this iteration of COVENANT.

2.1 Wake Model

Vaisala has conducted a multi-project validation study [2] of its unique wake loss estimation method, using one year of post-construction operational data from seven North American onshore wind energy projects in flat terrain. Observed wake losses were derived from the wind project SCADA data using a "reference set" approach to estimate the unwaked power. A mesoscale model simulation was used to determine the spatial variability of the unwaked wind field so that its signature could be removed from the observed estimate of wake losses. The pre-construction wake loss estimates were made with Vaisala's time series-based method utilizing the Larsen single turbine wake model. Finally, error metrics were calculated describing the difference between the modeled and observed wake losses. The results showed that the observed wake losses were 21% larger than predicted, on average, indicating the need for a calibrative correction to the wake loss estimate. Vaisala derived parameter adjustments in its wake model such that the modeled wake losses were calibrated with the observed wake losses from the validation study and proposes to implement the utilization of these adjustments in its wake model. This resulted in the mean bias error for all wind farm years in the COVENANT data set to change from -0.34% (Version 8.0) to 1.72%.

2.2 Loss Model

Vaisala's primary loss strategy is to maintain a loss model that is calibrated to the performance of the industry. Because the calibration of Vaisala's wake model resulted in a shift of the center (or mean) of the wind farm year energy error distribution from -0.34% to 1.72%, a number of Vaisala's standard loss factors have been adjusted such that the wind farm year energy error distribution was re-centered near zero. A summary of loss updates are shown in Figure 1.

The combination of wake model and loss adjustments has resulted in a process versioning update from 8.0 to 9.0.

Loss Category	Previous Standard Loss Value	Updated Standard Loss Value
Grid Availability	99.5%	99.8%
Total Electrical Efficiency	98.0%	97.5%
Turbine Performance	98.0%	99.0%
Blade Soiling	98.0% - 99.5%	98.5% - 99.5%
Blade Degradation	98.5% - 99.5%	99.0% - 99.5%

Table 1: Vaisala North America standard loss updates. Blade soiling and blade degradation losses vary depending on environmental conditions. Standard environmental loss factors less than 99.5% have been decreased by 0.5%.

3 PROCESS CHANGE ACCEPTANCE

In order to accept a methods change into standard practice, Vaisala has imposed acceptance criteria that must be met within the test. Table 2 describes the tests employed and the results from this test. In the event that a particular test fails, either the method is rejected or further analysis is performed on the projects generating the failed criteria and acceptance is granted with an exception.

The "blue curve" referenced in Table 2 is a normal distribution that matches the mean and standard deviation of the wind farm year percent errors. The "orange curve" referenced in Table 2 is a normal distribution with a mean of 0 and a standard deviation equal to the average model-estimated 1-year uncertainties of all the wind farm years in the validation study.

The "blue curve" and "orange curve" results from the currently proposed method changes can be found in Figure 1 of Section 4.

Category	Test	Result
Center (or Mean) of Error Distribution	The absolute value of change should be no more than 0.5% from the last mean	Failed
Center (or Mean) of Error Distribution	The mean itself (the center of the histogram or the deviation of the blue vertical line) should be less than +/- 1% from the center	Passed
Uncertainty (or Standard Deviation) of Error Distribution	Change from the prior iteration (i.e. the narrowing or widening of the blue bell curve) should be within 1.9% of the width from the previous iteration	Passed
Uncertainty (or Standard Deviation) of Error Distribution	The difference between the error distribution uncertainty and the average model-estimated uncertainty (i.e. the difference between the widths of the blue and orange bell curves) should be less than 2.0%	Failed
Uncertainty (or Standard Deviation) of Error Distribution	Change from prior iteration of the average model-estimated uncertainty (i.e. the narrowing or widening of the orange bell curve) should be less than +/- 1%	Passed
Change for Individual Projects	Change of the P50 energy estimate for any one project relative to the prior iteration should be less than +/- 2.5%	Passed
Change for Individual Projects	Change in the model-estimated 1-year uncertainty for any one project relative to the prior iteration should be less than +/- 2.5%	Passed

Table 2: Criteria for acceptance. (Colors refer to schema in Figure 2)

3.1 Exceptions To Test Criteria

Discussion regarding criteria failures shown above in Table 2.

3.1.1 Center of Error Distribution Failure

The failure of the absolute value of the change in the center (or mean) of error distribution being greater than 0.5% was the result of Vaisala intentionally adjusting loss factors so the center bias of the error distribution would be slightly positive (Vaisala's prediction more conservative than the actual).

3.1.2 Difference Between Width of Error Distribution

The failure of the difference between the error distribution uncertainty and the average model-estimated uncertainty criteria is an exception that was carried over from the previous COVENANT validated version [3]. For this proposed method change, the difference has decreased from 2.9% to 2.7%.

As this criteria failure was not caused by the proposed wake model and loss structure method update (and has actually led to an improvement compared to the previously validated version), Vaisala is accepting this method change. However, Vaisala will be addressing the differences between the error distribution width and the average uncertainty-model estimated width in an upcoming COVENANT process which evaluates long term reference length selection as well as tuning of the uncertainty models.

3.2 Conclusion

On the basis of the above test criteria, including consideration of the test exceptions, Vaisala has accepted this methods change into standard practice and is calling the version incorporating this change as Version 9.0.

4 RESULTS

The resulting histogram after Wake Model and Loss Structure Updates were implemented is shown below. Process versioning has been updated from 8.0 to 9.0.

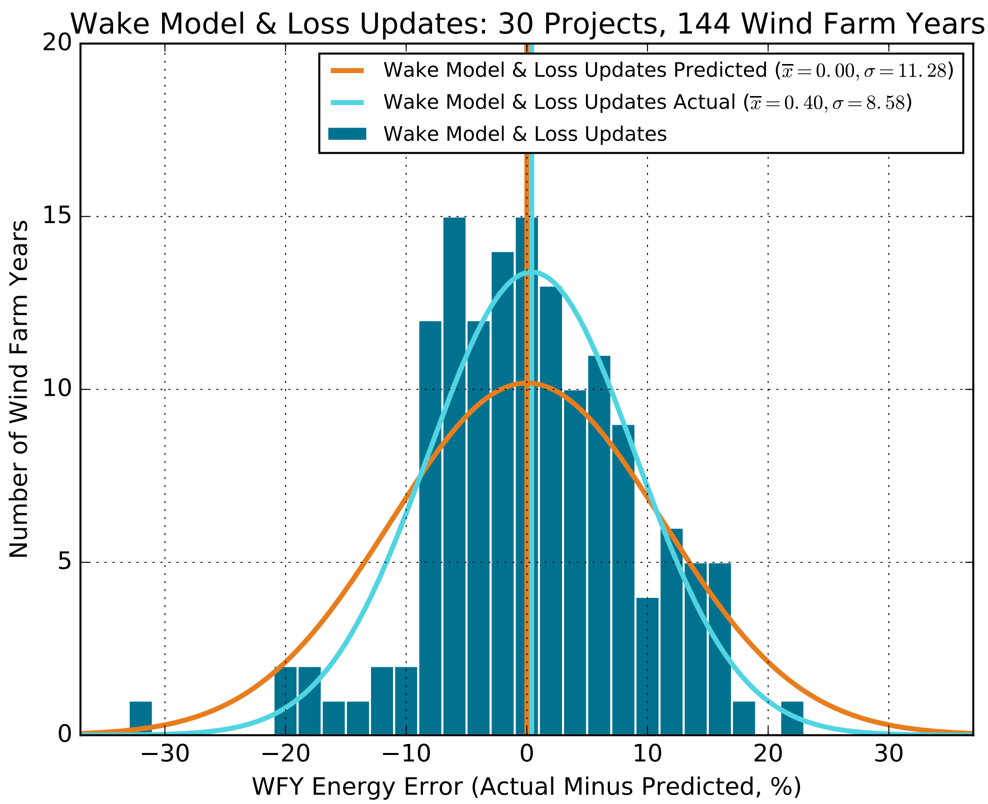

Figure 1: Resulting mean error histogram after Wake Model and Loss Structure Updates

	Version 8.0	**Version 9.0**
Mean Bias Error	-0.34%	$+0.40\%$
Actual Standard Deviation	8.42%	8.58%
Model-Estimated Standard Deviation	11.28%	11.28%

Table 3: Changes in mean error and standard deviation of the WFY error distribution histogram from Version 8.0 to Version 9.0.

REFERENCES

[1] M. Stoelinga and M. Hendrickson, "A Validation Study of Vaisala's Wind Energy Assessment Methods," tech. rep., Vaisala, 2015.

[2] M. Stoelinga, "A Multi-Project Validation Study of Vaisala's Wake Loss Estimation Method," tech. rep., Vaisala, 2019.

[3] Vaisala, "Vaisala 3TIER Services COVENANT Process: Methods Validation Update Report, Numerical Weather Prediction Updates," tech. rep., Vaisala, 2020.