BorealisWind
Ice Protection System

Improving Understanding and Estimation of Wind Turbine Icing Losses

Contents

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Estimating Icing Losses: Why is it Important?

As the wind energy industry continues to grow and expand, the significance of understanding and mitigating production losses due to icing becomes increasingly important. The accurate estimation of icing on turbine blades is essential for informed decision-making and sustainable asset management.

Correctly estimating icing losses requires the consideration of many variables, often resulting in significant underestimations. Patrice Roberge, Ph.D., Lead Data Scientist at Icetek, Inc., delves into the conventional methodologies employed for calculating icing losses, revealing common pitfalls and their consequential impacts. Daniela Roeper, P.Eng, Vice President of BorealisWind, contributes a global perspective, shedding light on the divergence between calculated market losses and on-site realities.

These insights underscore the imperative for the accurate estimation of icing losses throughout wind farm lifecycles. By addressing these challenges head-on, wind farm executives and operators can more effectively strategize pre-construction planning and operational management, safeguarding against production shortfalls and increasing return on investment.

Errors in the Estimation Process

The initial step involves accurately estimating available energy based on wind speed. Many wind farm operators rely on the manufacturer's power curve and nacelle wind speed. However, this combination can be highly inaccurate, particularly for sites with rugged terrain. The manufacturer's power curve is developed in a standard environment, and local topography effects may lead to significant deviations.

Even within a wind farm, variations in power curves among turbines can be substantial. **Factors such as temperature or the wake of nearby turbines can induce significant deviations.** If available energy is not accurately estimated, it can introduce a significant bias in subsequent icing loss calculations. Figure 1 presents a fictional case based on actual data comparing the difference between the learned power curve and the manufacturer's power curve. It is possible to observe that the difference between the expected power of the two power curves can exceed ±150 kW and this difference is different for the two turbines (T1 and T2).

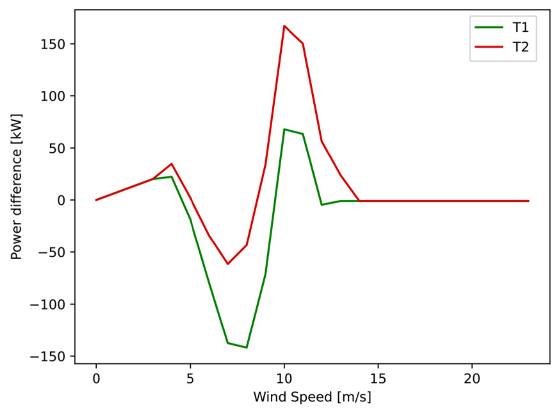

Figure 1: Example inspired by actual field data of the power difference between the learned and manufacturer's power curve for different wind speed and two turbines in the same wind farm (T1 and T2).

The second challenge lies in distinguishing the impact of icing conditions as a result of other factors (e.g., maintenance, faults, curtailment). Turbines report codes and events to identify such periods, but these are often incomplete and unreliable. Cleaning and validating the data is crucial for accurate estimation. Some operators may opt for shortcuts, such as assessing timespans when icing codes are active. Because these codes are generated when the turbine is stopped or producing less energy than expected due to icing, they may not capture all relevant events. Filtering out these events can result in overlooking significant icing losses.

Figure 2 illustrates a scenario based on real data, demonstrating a turbine affected by icing conditions. The solid green areas represent the power generated, while the expected power based on the power curve is depicted in red behind the green areas. Consequently, the visible red areas indicate the extent of the icing losses. At the top of the figure, turbine codes are shown: green indicates normal operation, purple indicates an active icing status code, and red represents a turbine code related to maintenance or errors. It is notable that the icing status codes only correspond to periods when the turbine is significantly producing less power than expected. In this fictional case, considering only the periods with icing codes would result in estimating icing losses at 90 MWh. However, the actual icing losses are 210 MWh, underscoring the limitations of relying solely on icing status codes to capture the full impact of icing-related power reductions.

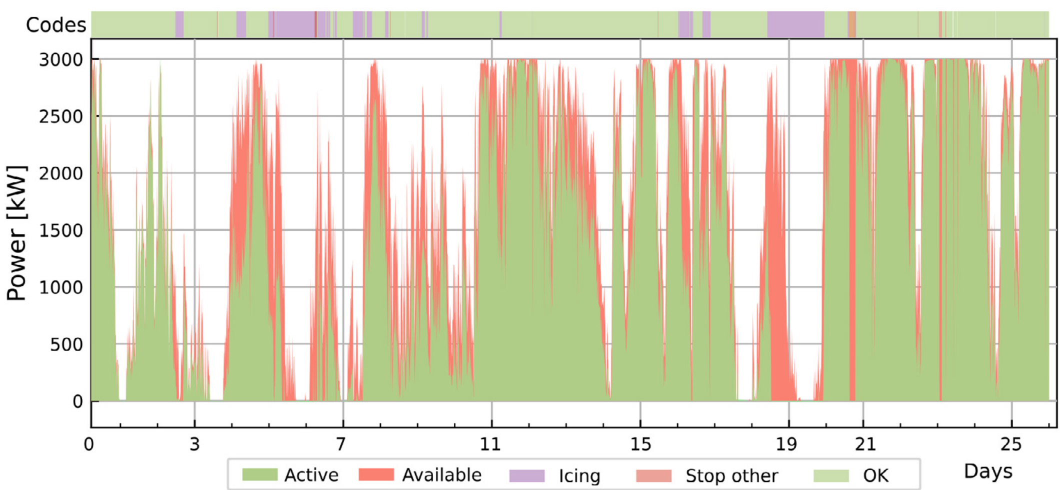

Figure 2: Sample case based on actual data of an icing event where the produced power (green) is compared to the expected power (red). The turbine status codes are presented on top of the figure (green = normal operation, purple = icing and red = maintenance or errors).

Impact on Annual Energy Production

The combination of these factors may lead to a substantial bias in estimating icing losses. **It has been observed that many wind farm operators underestimate their icing losses, with differences as high as 50% compared to previous estimates.** For example, for an average IEA ice class 4, this difference could account for 9% of the annual energy production (AEP).

Market Data

Looking more broadly at the global market, it is reasonable to assume that the actual impact of icing on wind turbines may be underestimated throughout the world. A study has been conducted including data from every wind farm in the world (thewindpower.net) and a complete meteorological icing frequency performed by VTT Technical Research Centre of Finland were combined. In this study, we were able to estimate the production loss due to icing for all wind farms worldwide using the work of the International Energy Agency (IEA) task 19.

Figure 3 shows the icing production loss per turbine at wind farms in the countries most affected by icing.

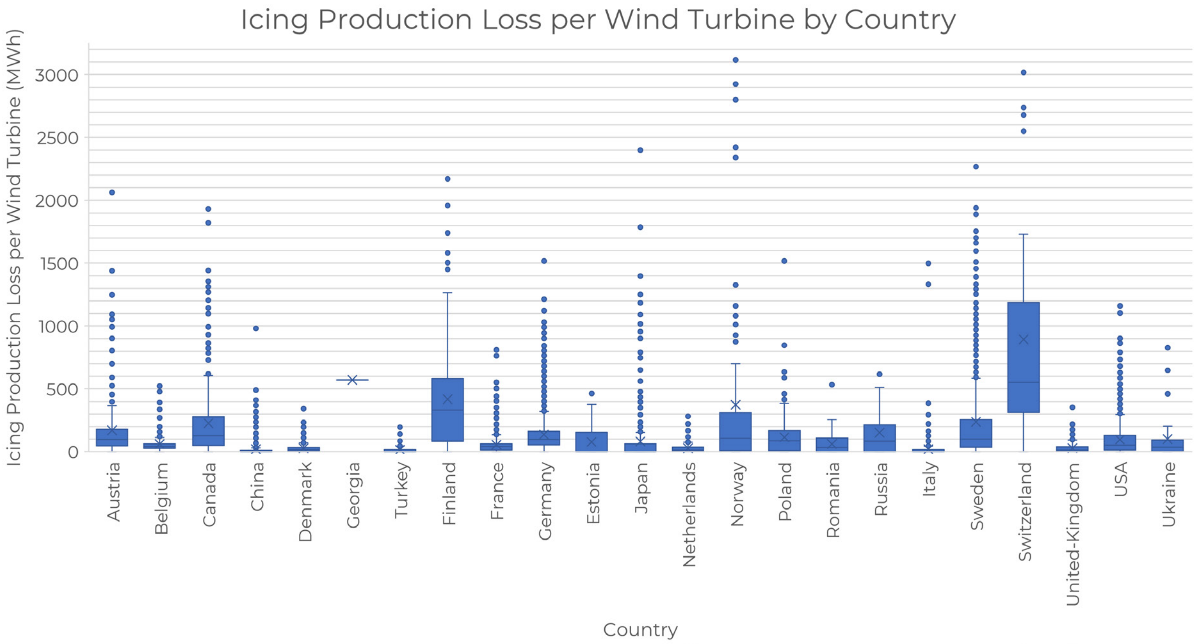

Figure 3: Distribution of icing losses per turbine for wind farms in 20 countries that icing conditions.

It is particularly of interest to see the significant quantity and intensity of the outliers in each country. Although the average icing in a country may seem low, depending on the location of the wind farm, they may still be subjected to severe icing conditions.

When this data is compared to individual sites where the actual icing losses are known, it is possible to observe a significant underestimation of icing impact. This observation aligns with the challenges related to the estimation process. It's important to note that the data contains multiple assumptions and therefore this should not be considered exact values, rather, as a global estimation of icing losses.

Conclusion

The errors related to the estimation of icing on turbine blades looms large, posing significant challenges to operational efficiency and energy production. As wind farm executives and owners plan for the future of their assets' performance and profitability, a comprehensive understanding of icing-related losses emerges as a critical assessment. By utilizing holistic estimation methodologies and leveraging real-world data, decision-making frameworks and bolster the resilience of the wind energy sector in the face of icing-related adversities.

DANIELA ROEPER, P. ENG

Vice President of BorealisWind

Daniela is a mechanical engineer with a passion for renewable energy and innovation. In 2016, she founded Borealis Wind, a company that provides a blade de-icing retrofit for wind turbines, increasing power production for cold climate wind farms. In 2023 Borealis Wind was acquired by FabricAir, and as the Vice President of the BorealisWind product line, we are scaling and making the technology available globally.

PATRICE ROBERGE, Ph.D

Lead Data Scientist, Icetek, Inc.

Patrice holds a Ph.D. and a master's degree in mechanical engineering as well as a bachelor's degree in engineering physics. Since 2016, his professional focus has revolved around projects in the field of wind energy in cold climate. Patrice has developed his expertise in managing field data related to wind turbine production at both Université Laval and Icetek. During his tenure at Icetek, he played a key role in the development of tools aimed at assisting wind farm operators in gaining a deeper understanding of their turbines' performance and making informed operational decisions.

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Find out how the BorealisWind Ice Protection System can decrease downtime and increase revenue generated by your wind turbines.

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Icetek

Icetek presents innovative solutions for optimizing wind energy generation in cold climate. The IC-1 ice conditions monitoring system enables early detection of icing, empowering operators to optimize ice mitigation strategies and reduce loss of production. Icetek offers precise data analysis services to determine the actual payback of implemented strategies.

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