

An improved approach for the determination of in-cloud icing at wind turbine sites

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THE PROJECT

Icing is an important issue when operating wind turbines in elevated or arctic areas as it can cause significant production losses and represent a safety risk. In 2004, a 600 kW Enercon E-40 wind turbine with integrated blade heating was installed on Gütsch mountain, central Switzerland, at 2'300 m asl. Coincidentally, a fully equipped test station of the Swiss meteorological network SwissMetNet was installed about 200 m away from the wind turbine in 2003 (Fig. 1). The immediate proximity of the two facilities operating under icing conditions led to the launch of the research project "Alpine Test Site Gütsch: meteorological measurements and wind turbine performance analysis" which is embedded in the European "COST Action 727: measuring and forecasting atmospheric icing on structures".



THE METHOD

A common approach to define icing conditions is:

- air temperature below 0°C
- relative humidity higher than 95%

However, this method was found to be not very accurate so far. For the Guetsch project, a third parameter was therefore introduced:

- is the wind turbine in-cloud or not?

The information, if the wind turbine is in-cloud or not, is gained by measurements of the **incoming long wave radiation L_{\downarrow}** , which allows the calculation of the **sky temperature T_{sky}** according to Stefan-Boltzmann's law. By comparison of T_{Air} and T_{Sky} , it can be determined if the wind turbine is in-cloud or not.

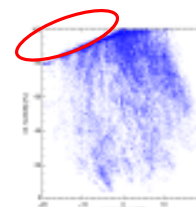


THE RESULTS

At the nacelle of the Guetsch wind turbine, measurements of air temperature, relative humidity and incoming longwave radiation were in-stalled. The gained results were compared to webcam images of the rotor blades.



The data analysis showed, that relative humidity was measured based on saturation water vapor pressure with respect to water (WMO standard). But below 0°C, saturation cannot be reached anymore using this procedure. Therefore, the readings for relative humidity have to be recalculated with respect to saturation water vapor pressure over ice for temperatures below 0°C. This procedure leads to an improvement of the detection of about 10%.

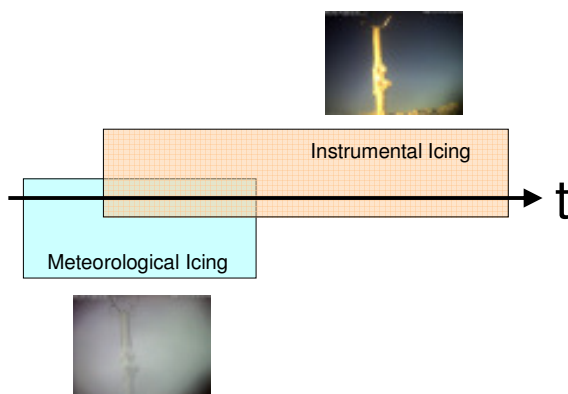


First analysis of the winter 2007/08 data shows, that the introduction of the in-cloud parameter (incoming long wave radiation) for detecting icing conditions leads to an improvement of the detection of again about 10%.

METEOROLOGICAL AND INSTRUMENTAL ICING

Meteorological icing M_{icing} is defined as the duration of a meteorological event or perturbation which causes icing.

Instrument icing I_{icing} is defined as the duration of the technical perturbation of an instrument due to icing.



When analyzing measured wind data for wind assessments without availability of additional measurements, it is impossible to distinguish the duration of meteorological and instrumental icing. However, this information is crucial when calculating energy yields e.g. assuming the availability of a blade heating.

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