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Site assessment for a type certification icing class

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Introduction

Icing climate sites offer commonly favorable wind conditions and mostly low populated areas, but the structural safety and reliability of wind turbines can be affected as well as the economic efficiency [1], [5]. Present international guidelines and standards [2], [3] focus on the structural safety under normal climatic conditions, but consider icing effects only to a limited extend. The results, as the aerodynamic and structural modelling of blade icing with respect to wind turbine loading, have already been included in the new edition of IEC 61400-1 [4] (under development). However, especially the site assessment for icing conditions is described only to a very marginal extend in all guidelines and standards. Site assessment is essential to judge whether a specific site showing icing conditions requires turbines with icing class type certification or not. Presently, DNV GL is developing a best practice for the certification of wind turbines under icing conditions.

Objectives

Site assessment for icing conditions is described, based on four approaches for an example site in Germany. The instrumental icing duration (taken equivalent to the rotor icing duration) is the main parameter to judge if a specific site showing icing conditions requires turbines with icing class type certification or not. Based on this, the site conditions can be connected to the type certification icing class, as being proposed in [1].

Methods

Meteorological icing is the period during which the meteorological conditions allow ice accretion; instrumental (rotor) icing is the period during which the ice is present/visible at a structure and/or a meteorological instrument or rotor blades [7]. Four approaches are described and evaluated for the example site "Rödeser Berg" at 385m ground height above sea level to estimate the icing durations. The reference site of Fraunhofer IWES is located in an icing relevant area in the middle of Germany where a 200m meteorological mast is installed, being equipped with more than 40 meteorological sensors, see Fig. 1.:

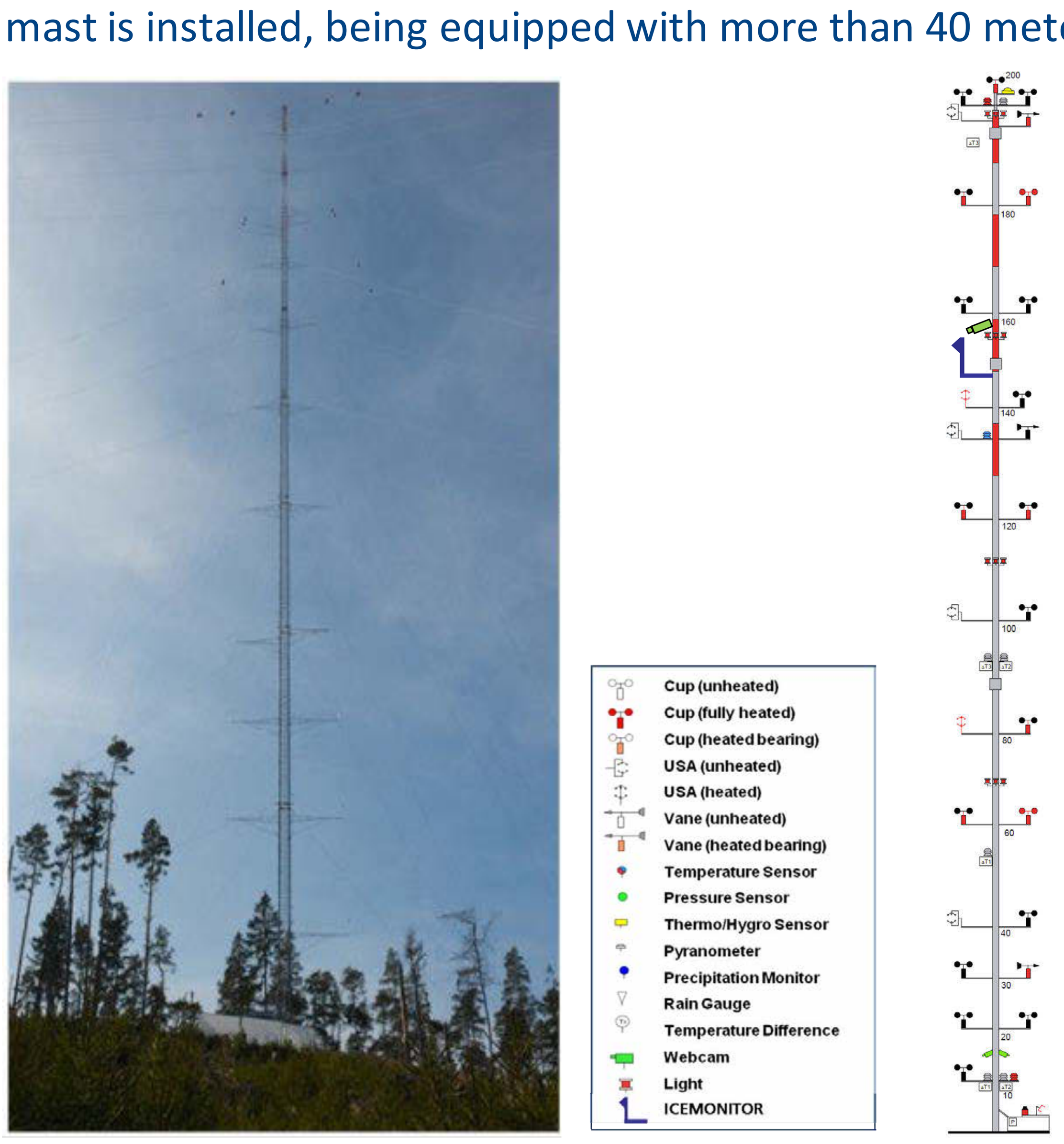

Fig. 1: Fraunhofer IWES met mast and sensor locations

1. Measurement of instrumental icing using ice sensor ICEMONITOR (Fig. 2 upper plot, red line) and camera (upper plot, magenta crosses), installed at 145m altitude.

2. Measurement of instrumental icing at several heights between 10m and 191m using one heated ultrasonic anemometer (reference) and one unheated cup (upper plot, green and blue lines), additionally air temperature and relative humidity (lower plot, blue and red lines). This approach combined with manual camera verification is used as reference for other approaches.

3. Measurement of meteorological icing duration based on meteorological sensors (air temperature and gradient, relative humidity, wind velocity) and sky conditions using a ceilometer (lower plot, black circles). Additionally, the application of machine learning procedures, developed by Fraunhofer IWES for Rödeser Berg site [8], help to determine the instrumental icing duration.

4. Application of icing maps for long term correlations.

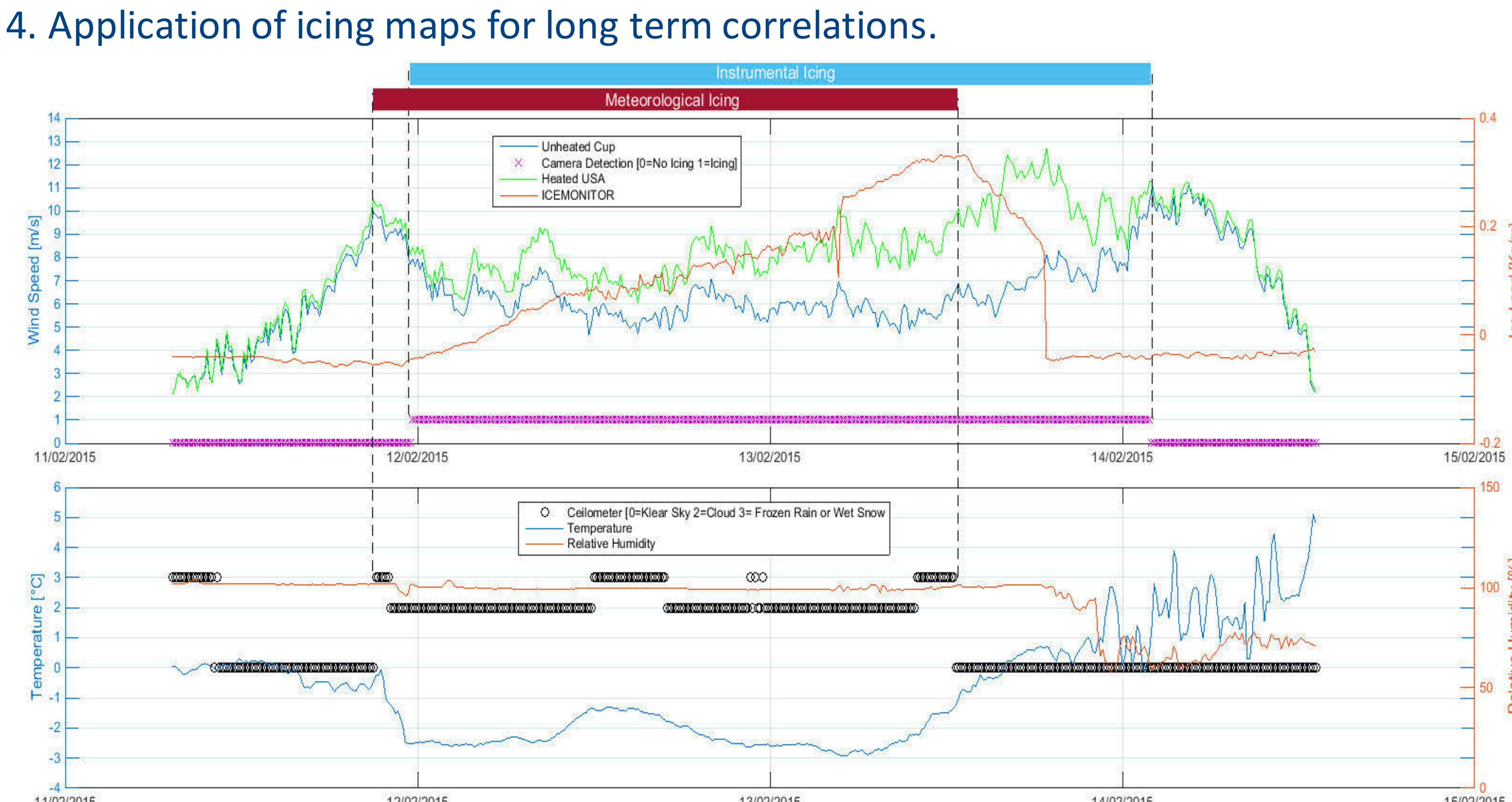

Fig. 2: Example time series for approaches 1 to 3

Results and Conclusions

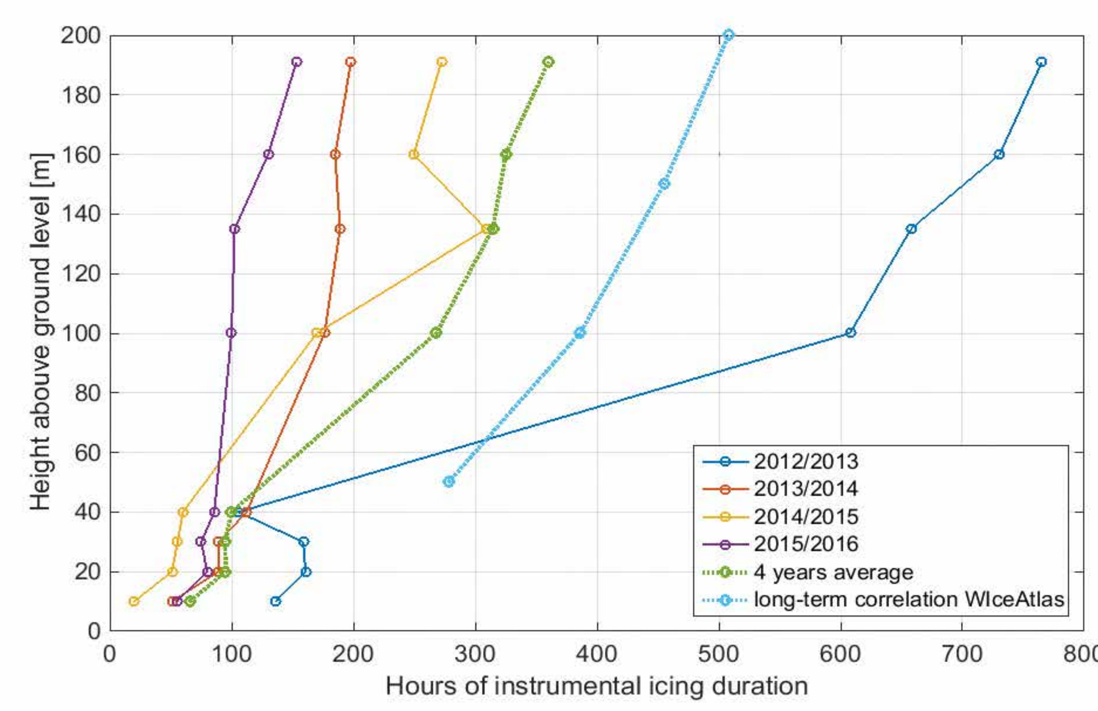

Figure 3 shows the instrumental icing duration for the four observed winters at met mast heights from 10m to 191m above ground level (agl). Significant variations of the instrumental icing duration among the different winters are observed, i.e. 150h to 770h per year at 191m agl. Height dependent icing durations can occur, partly with adverse gradients.

Fig. 3: Instrumental icing duration for four winters at different met mast heights

- Camera observations were highly reliable. ICEMONITOR can show high failure sensitivity, (approach 1).

- For approach 2 sufficient and reliable power supply for the heated anemometer must be ensured to avoid ice influence. The recommended setup and boundary conditions are: The difference between the heated ultrasonic and the unheated cup anemometer (at same mast height) must be at least twice the sum of the two uncertainty ranges of both anemometers; mast shadowing must be avoided. The temperature must be below +2˚C and the relative humidity above 85% at start of the instrumental icing.

- For approach 3 the application of machine learning procedures using solely meteorological data seem promising, but it may be site specific [8]. For a general statement on the transferability to other sites, more testing on these procedure will be undertaken over the next months. Meteorological boundary conditions for instrumental icing at the site Rödeser Berg are: The lower limit for relative humidity is 85%; above 100% (oversaturation) and temperature below +3˚C a very high probability exists; highest probabilities occur between -5˚C and +2˚C, extreme low probabilities below -10˚C.

- The "WIceAtlas map" [9] categorizes Rödeser Berg as IEA ice class 2 according to [7]. The long term correlation (20 years) based on the "WIceAtlas map" shows a correction factor of about 1.3 to the four years average, see Fig. 3 (approach 4). The German icing map [6] estimates about 360h per year meteorological and 470h instrumental icing per year at 10m agl. This map should be used only as a first approximation, since the spatial resolution is limited and specific site conditions (exposures, sheltering) are not considered [6].

- Conversion factors from meteorological to instrumental icing duration are about 1.4 at Rödeser Berg during the measured winters, fitting well to the mean value of 1.3 of the German icing map [6] and still quite well to the IEA mean conversion factor of 2 to 3 [7].

- Icing durations can differ strongly between winters. Icing durations must be measured over at least one year. A long term correlation (≥ 10 years) using data e.g. from nearby weather stations, wind turbines or high resolved icing maps must be carried out.

- **Main conclusion:** The rotor (=instrumental) icing duration of wind turbines at a given site can be determined based on different approaches and data sets. The obtained rotor icing duration needs to be compared with the proposed ice class for type certification [1] to judge if a turbine with ice class certification is required for this site. The final aim is to ensure the turbines' structural safety and reliability and sufficient energy output.

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