Icing: Consequences for the operation and power production of wind turbines in the Jura Mountains, Switzerland

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Sara Koller, René Cattin, Saskia Bourgeois
Meteotest, Bern, Switzerland

Objectives

The Swiss Federal Office of Energy has set focus points to investigate icing on wind turbines within their research program "Wind Energy". This research project aimed at addressing the consequences for the operation and power production of wind turbines in the Jura Mountains under icing conditions.

Methods

Investigations comprised the following five aspects:

1) **Monitoring of the icing conditions** on the nacelle and on the rotor blades with webcams.
2) **Assessing the icing frequency** as well as typical temperatures and wind conditions leading to icing.
3) Evaluation of different methods for **ice detection on the rotor blades** of the wind turbines:
   3a) Comparison of the actual power production with the theoretical power curve
   3b) Temperature and relative humidity
4) Assessing efficiency, cost and benefit of the Enercon **blade heating** based on the webcam images.
5) **Field studies of ice throw** at the two sites.

Results

1) Webcams are a very suitable tool to monitor icing on nacelle and rotor blades.

Figure 1: Webcams monitoring rotor blades (left) and anemometer on nacelle (right).

2) Instrumental icing occurs during approximately 60 days in the Jura Mountains, meteorological icing during 15 days (Fig.2).

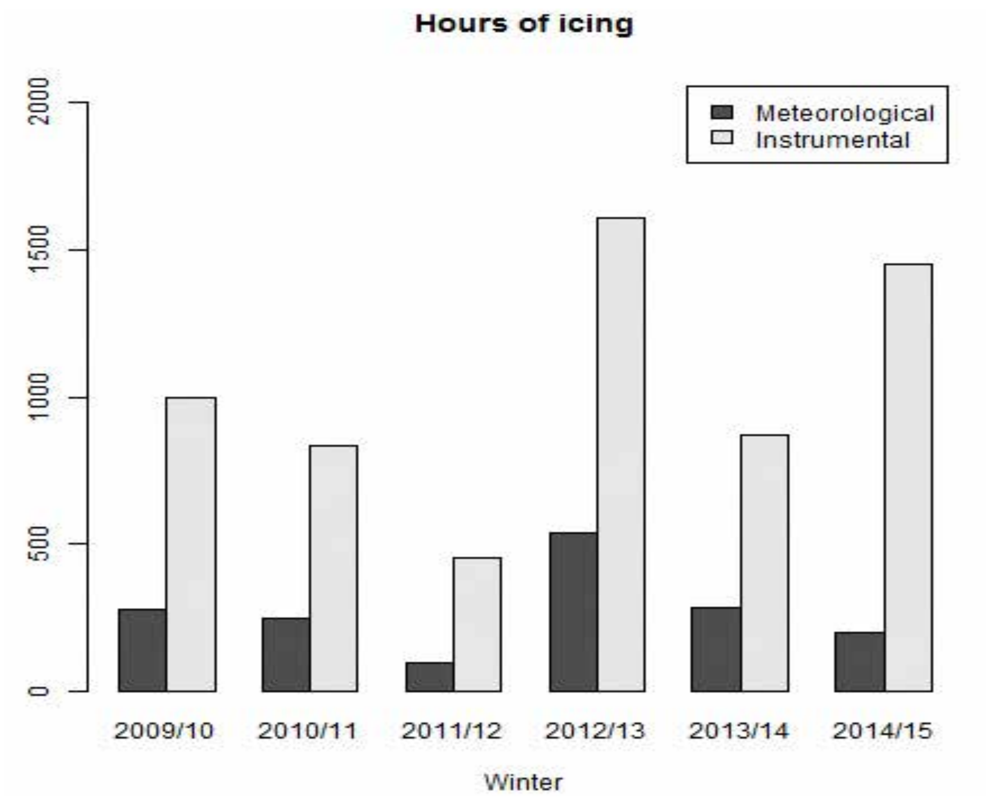

Figure 2: The hours of meteorological and instrumental icing during the six winters measured at the St. Brais wind park site.

3) Icing detection:
3a) Comparison of the actual power production with the theoretical power curve showed to be a suitable tool to detect icing.
3b) Evaluation of temperature and relative humidity overestimated the periods of icing conditions (Fig. 3 and Fig. 4).

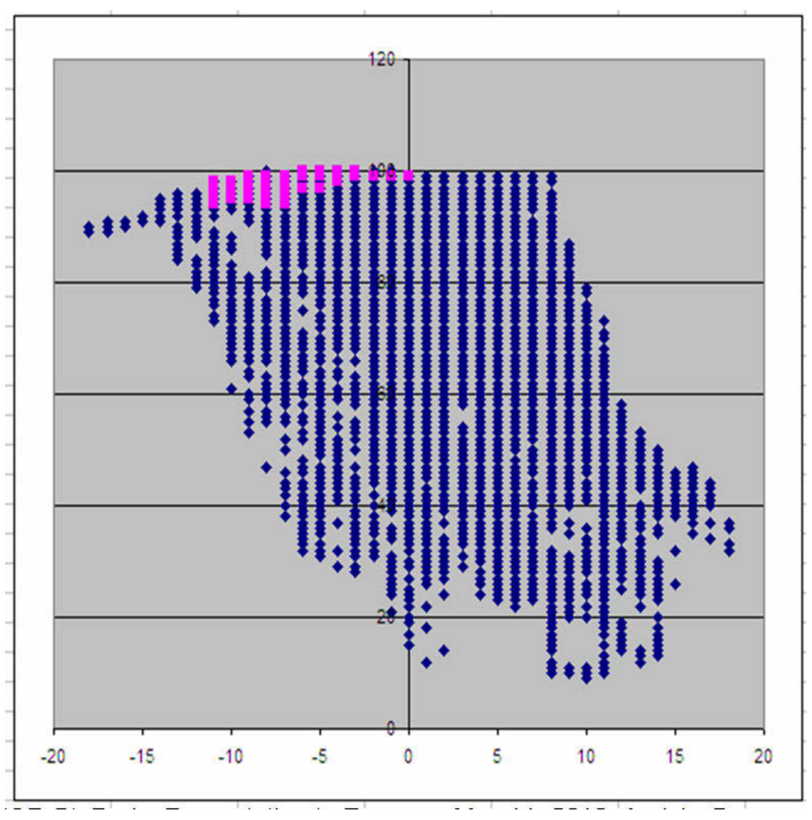

Figure 3: Blue: The relationship between temperature and relative humidity at St. Brais during the winter 2009/10. Saturation is not reached at temperatures below ca. -7° C. Pink: Measurements made during icing events.

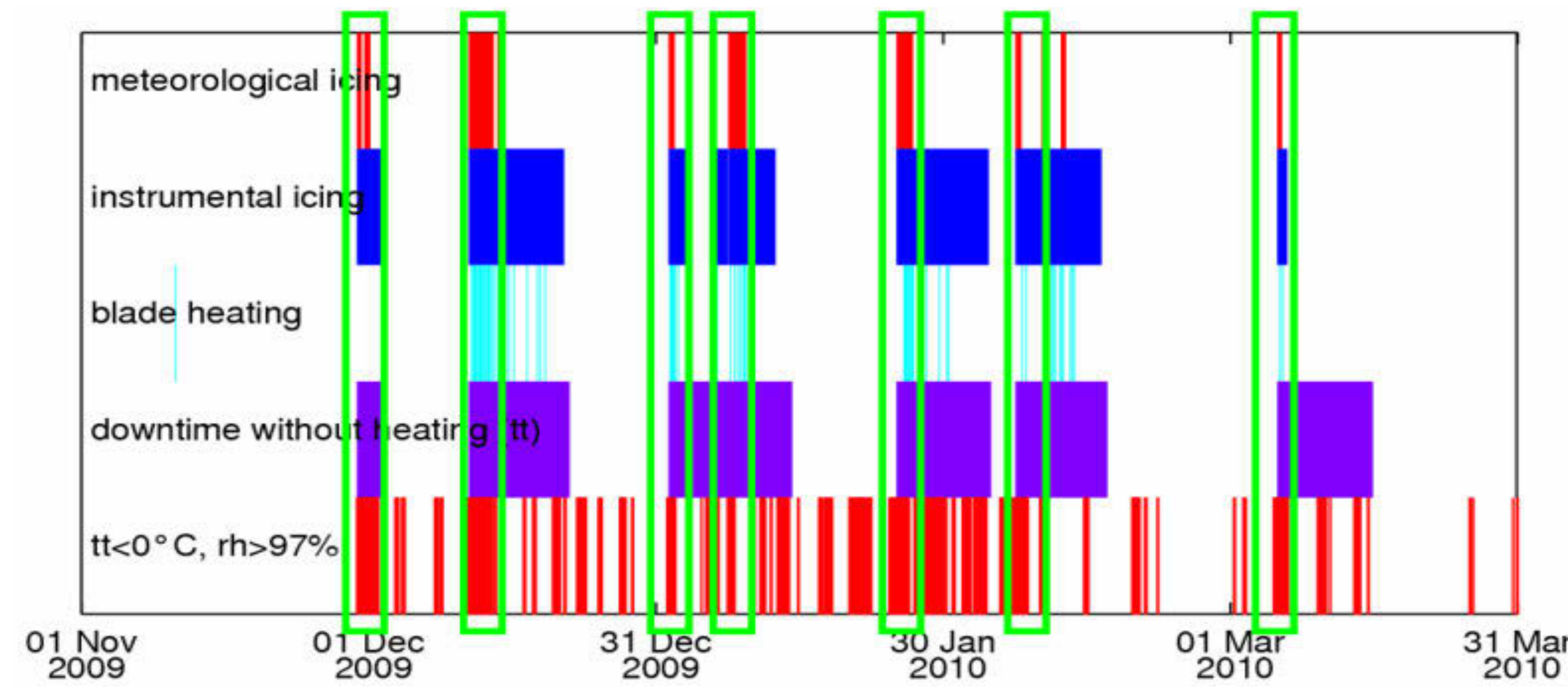

Figure 4: Periods when air temperature was below the freezing point and relative humidity was above 97% (bottommost row), compared with instrumental icing. The green boxes mark the periods with meteorological icing.

4) The analysis of the data showed that the power production was higher when heating during operation, as opposed to heating at stand-still (Tab. 1).

Table 1: Heating power consumed compared with production losses due to deactivation of the heating (WEA 2: heated).

Event start	Event end	Production WEA 2 [kWh]
Jan 6, 2010 6:48 pm	Jan 7, 2010 4:30 pm	3,892
Jan 25, 2010 8:01 pm	Feb 2, 2010 6:41 pm	96,608
Feb 7, 2010 11:35 am	Feb 8, 2010 8:27 pm	2,993
Production loss WEA 1		**103,493**
Energy saved due to deactivation of blade heating		-7,020
Production loss total WEA 1		**96,473**

5) 75% of all ice particles collected were found within 0 to 0.6 x the tip height. No ice particles were found at distances larger than 1.4 x tip (Fig. 5).

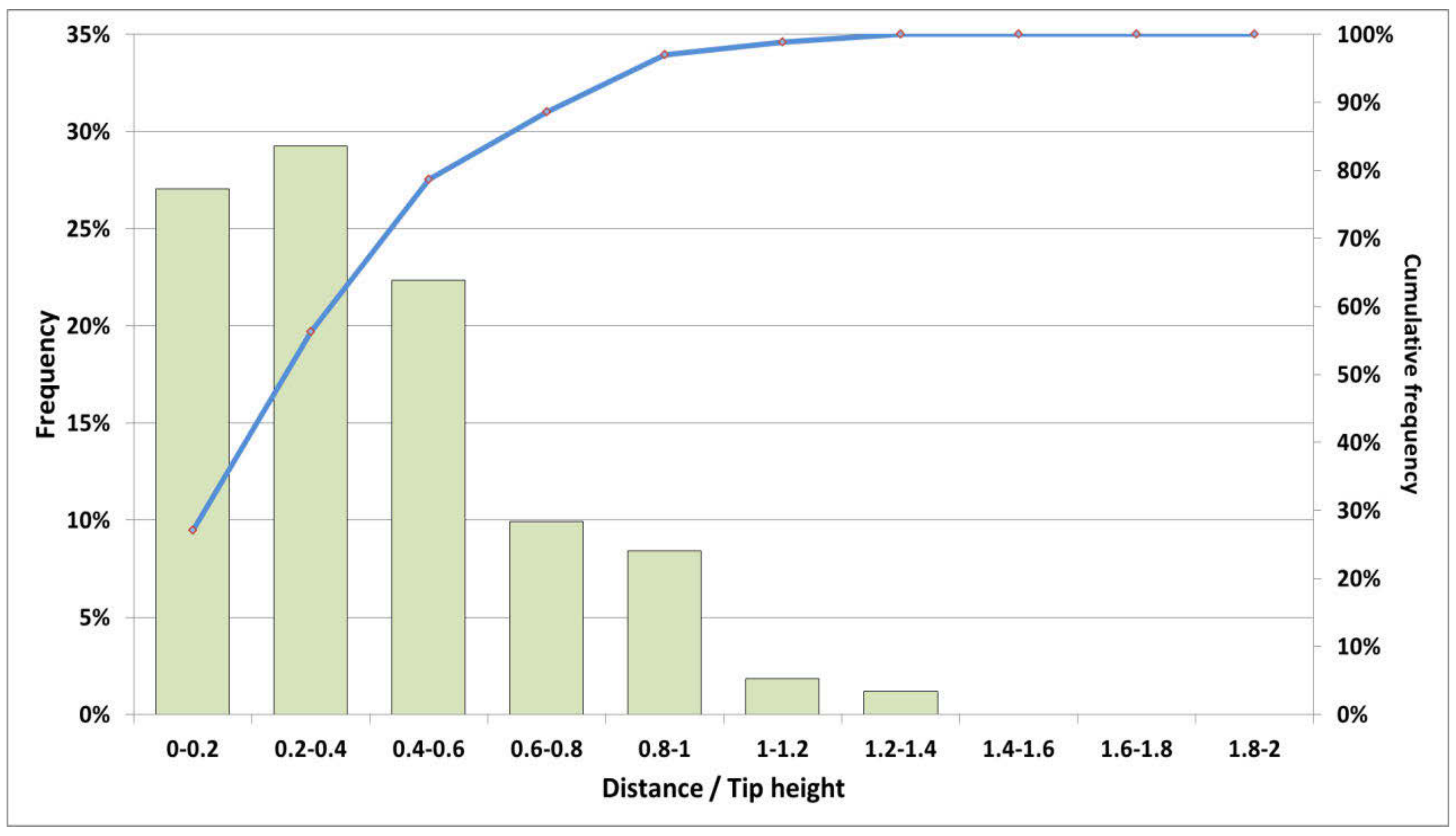

Figure 5: Frequency distribution of the ice particles collected (Gütsch, St. Brais, Mont Crosin) depending on the distance, normalised with the tip height of each turbine.

Conclusions

Wind energy is increasingly being used in cold climates, and technology has to adapt to meet these challenges.
The research project in the Jura Mountains was able to add valuables experiences for turbine manufacturers and project developers to overcome questions in planning and operating wind parks in cold climate.

References

ICING AT ST. BRAIS AND MONT CROSIN, Consequences of icing for the operation and power production of wind turbines in the Jura Mountains. Executive Summary, April 6 2016. Swiss Federal Office of Energy.