Wind turbine ice throw studies in the Swiss Alps

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WIND TURBINE ICE THROW STUDIES IN THE SWISS ALPS

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ABSTRACT

Icing is an important issue when operating wind turbines in high altitude 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, Switzerland, at 2'300 m asl. Coincidentally, a fully equipped test station of the Swiss meteorological network SwissMetNet is situated about 200 m from the wind turbine. The immediate proximity of the two facilities operating under icing conditions led to the launch of the national research project "Alpine Test Site Gütsch" which is embedded in the European "COST Action 727: measuring and forecasting atmospheric icing on structures".

As the wind turbine is located close to ski slopes, ice throw is an important safety issue. Since October 2005, the area around the wind turbine was inspected after every icing event for ice fragments that had fallen off the blades. Distance from and direction relative to the turbine as well as size and weight of the recovered fragments were mapped and, together with photos, collected in a data base. After data analysis, the following main conclusions could be drawn:

- Ice throw from the wind turbine occurs regularly during icing events at Gütsch.
- Ice throw can happen at any time of the year, even in summer.
- Most of the ice throw occurs underneath the blades of the wind turbine. This is therefore the most dangerous area.
- Ice throw is a significant safety risk at Gütsch.

1. INTRODUCTION

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 [1]. 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" [2] which is embedded in the European "COST Action 727: measuring and forecasting atmospheric icing on structures" [3].

Figure 1: Alpine Test Site Gütsch.

2. SITE DESCRIPTION

The test site is located on a ridge in highly complex terrain in the midst of the Swiss alps at 2’300 m asl (Fig. 2). The prevailing wind directions are north and south (Foehn). Winds are very variable and during strong Foehn events, wind speeds can easily reach 120 km/h or more. The long term average monthly air temperature varies from -6.9°C in February to 7.3°C in July and drops below 0°C from November to April. The main icing periods are late autumn and early spring when the temperature often lies around 0°C. Icing can occur throughout the year. In mid winter the temperature can fall below -20°C.

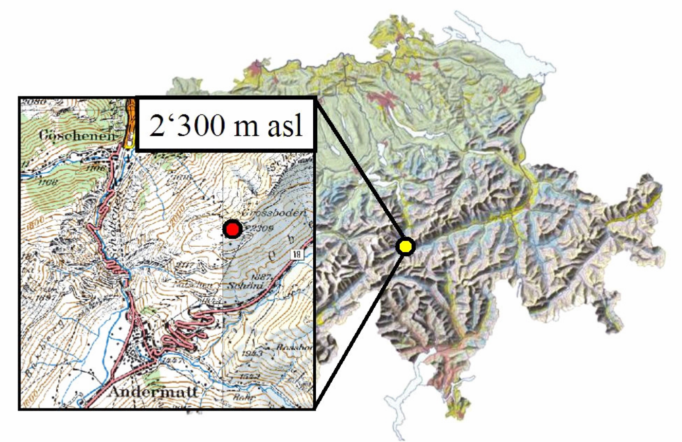

Figure 2: Location of the Alpine Test Site Gütsch.

3. METHOD

As the wind turbine is located close to ski slopes, ice throw is an important safety issue [4]. In order to achieve more information about the ice throw of the wind turbine, the area around the wind turbine was, if accessible, inspected after every icing event by a local person for ice fragments that had fallen off the blades. Distance from and direction relative to the turbine as well as size and weight of the recovered fragments were mapped and, together with photos (Fig. 3), collected in a data base. The following instrumentation was used for the documentation:

- Laser Distance Sensor (distance to wind turbine)
- Compass (angle relative to wind turbine)
- Spring balance (weight of ice fragment)
- Measuring stick (size of ice fragment)
- Digital camera (photos of the ice fragment)

Figure 3: Photo of ice fragments

4. RESULTS

During the winters 2005/06 and 06/07, 121 ice fragments with a maximum length of more than 100 cm and a weight of up to 1’800 g could be recorded in distances of up to 92 m from the wind turbine. Due to the exceptionally warm weather, there were only few icing events on Gütsch during winter 2006/07 and therefore only 13 fragments could be found in this period. 94 fragments were recorded during winter 2005/06 whereas 14 fragments resulted from two icing events in August 2006. As the site was not accessible after every icing event, it has to be assumed that the number of collected ice fragments is lower than in reality.

Figure 4 shows the distribution of the recorded fragments around the wind turbine. It is obvious that most of the ice fragments come to land South of the wind turbine. This seems plausible as icing most likely occurs during situations with winds from the North whereas air from the South is often dried out by the Foehn effect and therefore only rarely causes any icing.

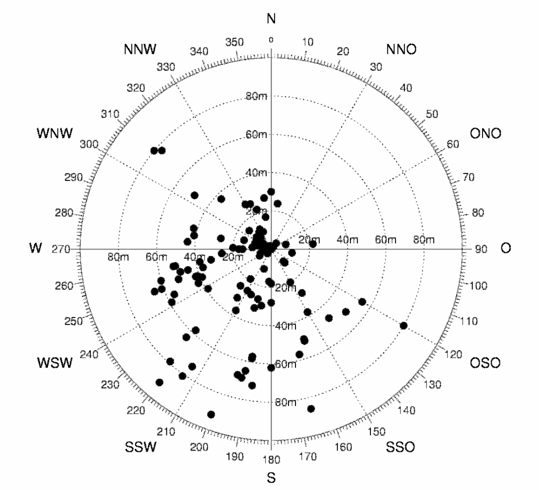

Figure 4: Distribution of ice throw relative to the wind turbine.

Figure 5 shows the frequency of found fragments for different distance classes. It can be seen, that almost 40% of the ice was found within a distance of 20 m (length of the rotor blade) or less around the wind turbine. The maximum throwing distance was 92m.

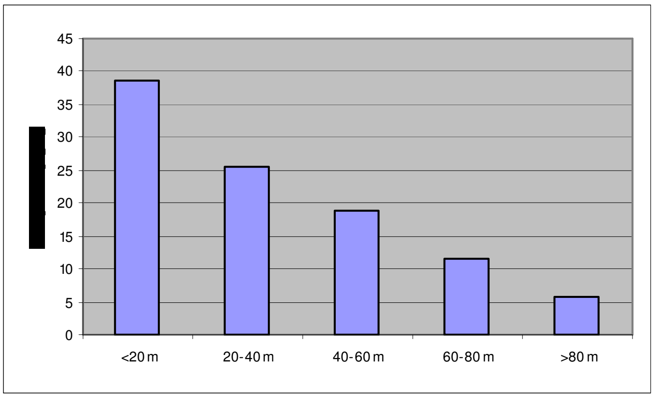

Figure 5: Frequency distribution of ice throw for different throwing distance classes.

The maximum throwing distance of d = 135 m according to the simplified empirical equation by [4]

$$d = (D+H) \cdot 1.5$$

D = rotor diameter [Gütsch: 40 m]
H = hub height [Gütsch: 50m]

was not reached during this study so far.

The maximum weight of an ice fragment was 1'800 g. When an ice fragment was broken into pieces on ground, all parts were weighted together. Figure 6 shows the frequency of ice throw for different weight classes. Almost 50% of the found fragments had a weight of 50g or less.

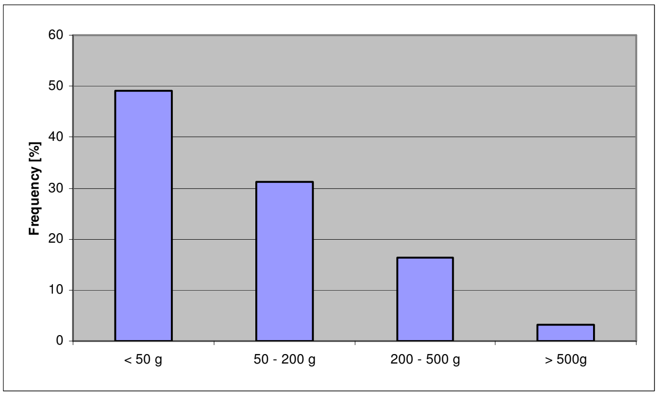

Figure 6: Frequency distribution of ice throw for different weight classes.

Figure 7 shows the relationship between weight and distance of the ice fragments. It can be clearly seen, that the throwing distance is independent of the ice fragment's weight.

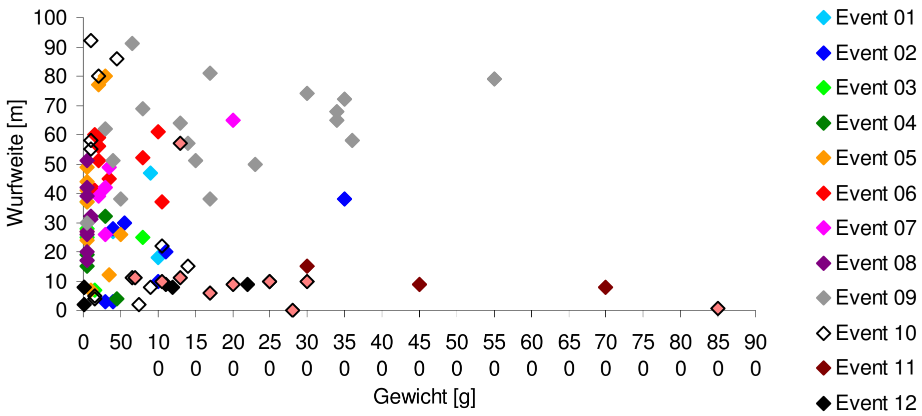

Figure 7: Ice fragment's weight versus throwing distance.

In order to get information about the relation between wind speed and distance of some of the ice throw cases, the average wind speed during the period where the ice fragment could be fallen off the blade (most likely during or shortly after a blade heating sequence) was estimated and plotted against the throwing distance. The result is illustrated in Figure 8 and shows a clear correlation between wind speed and distance of the ice throw (dashed line).

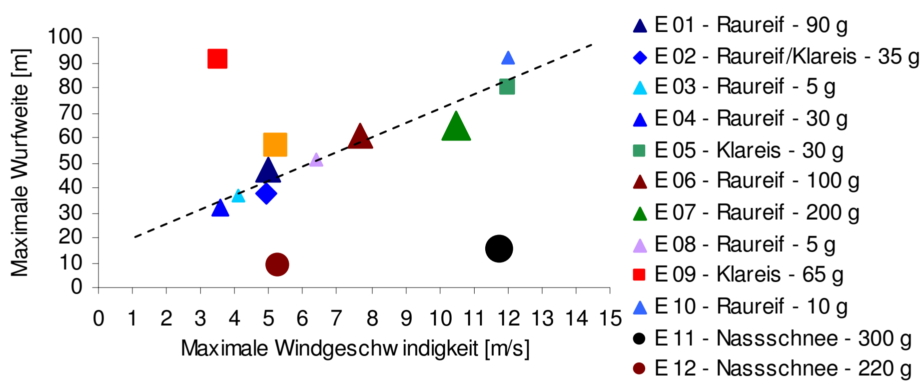

Figure 8: Wind speed versus throwing distance.

When mapping the ice fragments on site, the attempt was made to classify the type of ice into rime ice, clear ice or wet snow. Figure 9 shows the distribution of the different ice types around the wind turbine. It can be seen, that rime ice was found only on the southern side of the wind turbine whereas clear ice also appeared on the northern side of the wind turbine. Wet snow fragments were only found in the immediate proximity of the wind turbine.

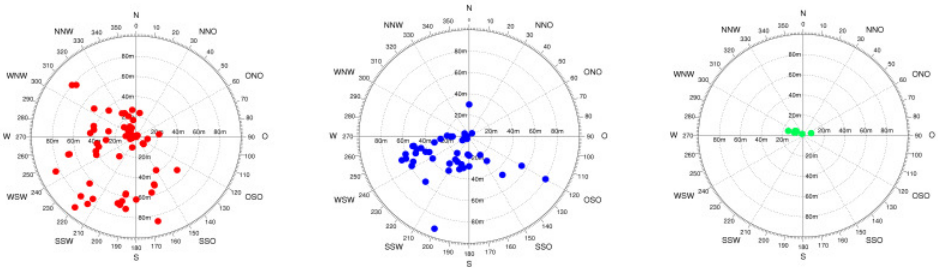

Figure 9: Distribution of ice throw around the wind turbine for clear ice (left, red), rime ice (middle, blue) and wet snow (right, green).

5. CONCLUSIONS

- Ice throw from the wind turbine occurs regularly during icing events at the Gütsch site.
- Ice throw can happen at any time of the year, even in summer.
- Most of the ice throw occurs underneath the blades of the wind turbine. This is therefore the most dangerous area.
- The maximum throwing distance given by the empirical formula [4] was not reached on Gütsch so far.
- Most of the ice fragments have a rather small weight. Nevertheless, the ice fragments can have weights up to 1.8 kg.
- There is no relationship between the weight of the ice fragment and the throwing distance.
- The throwing distance is dependent from the wind speed when the ice falls of the blade.
- Ice throw is a significant safety risk at the Gütsch site. Therefore warning signs have been installed and a nearby winter walking trail was placed further away from the wind turbine.

The study will be continued during the last project winter 2007/08.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] Laakso T., Holttinen H., Ronsten G., Tallhaug L., Horbaty R., Baring-Gould I., Lacroix A., Peltola E., Tammelin B., 2003, State-of-the-art of wind energy in cold climates

[2] www.meteotest.ch/cost727/index.html

[3] COST Action 727: Memorandum of understanding

[4] Seifert H., Westerhellweg A., Kröning J., 2003, Risk analysis of ice throw from wind turbines, Proceedings of BOREAS VI