ALPINE TEST SITE GÜTSCH: MONITORING OF A WIND TURBINE UNDER ICING CONDITIONS

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Summary

In 2004, an Enercon E-40 wind turbine with blade heating was installed on Gütsch mountain, Switzerland, at 2'300 m asl. A test station of the Swiss meteorological network SwissMetNet was installed nearby in 2003. The proximity of the two facilities operating under icing conditions led to the launch of the research project "Alpine Test Site Gütsch" which is embedded in the European "COST Action 727".

The project's main goals reside in an inter-comparison of different ice detectors and in the monitoring of the wind turbine performance under icing conditions. The investigations will take place during the winters 2006/07 and 2007/08. Initial observations were started during winter 2005/06.

In order to enable a visual observation of the rotor blades, a web cam was mounted on the nacelle of the wind turbine. By the use of motion detection, a picture of the passing rotor blade is taken. The images are sent to the project's website and updated every 30 minutes.

As the wind turbine is located close to ski slopes, ice throw is an important safety issue. 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.

The wind turbine detects by comparing effective power production to the power curve. This procedure does not produce satisfactory results with light icing or at low wind speeds. Therefore, additional measurements were installed on the nacelle of the wind turbine in order to be able to detect such conditions and start heating manually.

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.

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

Fig. 1: Alpine Test Site Gütsch.

2. THE PROJECT

The project "Alpine Test Site Gütsch" is coordinated by the Federal Office of Climatology and Meteorology MeteoSwiss and the private met office Meteotest. The project partners come from federal offices as well as industrial facilities.

The project's main goals are:

- collect meteorological data during icing events
- test and compare different ice detectors
- monitor wind turbine performance
- install visual observation of rotor blades
- monitor wind turbine‘s ice throw
- monitor and optimize blade heating

The project was started in September 2005 and has a duration of three years. The project’s first winter period 2005/6 was designated as a test period in order to establish and stabilize the data acquisition as well as to install first measurements at the met station and the wind turbine. Some of the first results gained during winter 2005/6 are described in this paper.

3. 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 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.

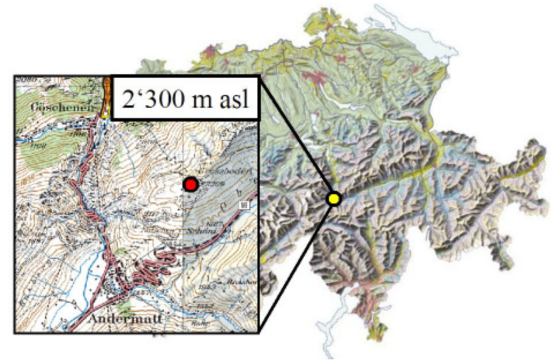

Fig. 2: Location of the Alpine Test Site Gütsch.

4. VISUAL OBSERVATION OF ROTOR BLADES

The availability of continuous live images of the wind turbine's blades is crucial for the performance analysis under icing conditions. During recent projects, the cameras were installed inside or outside the hub pointing towards the blade [3]. In this project, another approach was developed: A commercially available Mobotix web cam was installed on the nacelle of the wind turbine (Fig. 3).

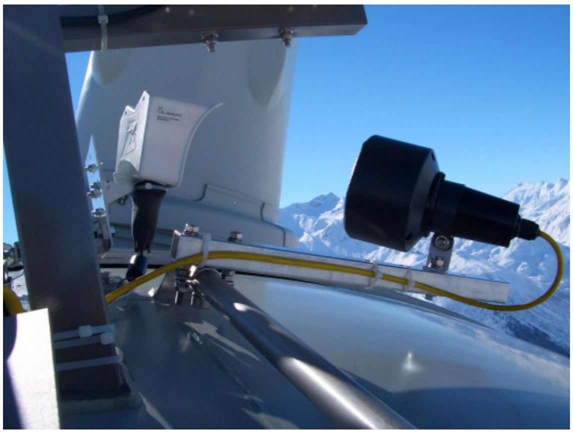

Fig. 3: Web cam mounted on the nacelle of the wind turbine. The lamp on the right is for heating purposes

The passing blade is detected by the use of video motion detection: A sensitive area within the image is defined. In this area, the changing of pixel brightness of two succeeding images is evaluated. If a certain percentage of pixels within this area has changed, this is considered as motion and the image is stored in the camera’s internal memory.

The testing of this procedure during winter 2005/6 was very successful and already provided a large number of high quality images (Fig. 4). However, the image transfer during winter 2005/6 was done by GSM which only allowed manual download of images and was time consuming as well as expensive. Therefore, no continuous image series were available. As the functionality of the system was proven, a broadband internet connection was installed. Now, an image of the blade is recorded and automatically sent to the project’s ftp server. The images are updated every 30 minutes on the project’s website. Furthermore, all the images are stored in the project's database for further evaluation.

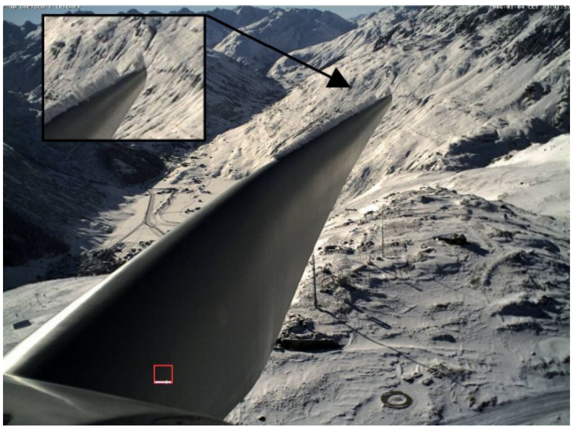

Fig. 4: Image taken by the web cam at the wind turbine’s nacelle showing the wind turbine’s blade with rime icing. The red square marks the sensitive area of the video motion detection.

A second web cam pointing to the ultrasonic anemometer at the wind turbine's nacelle was installed as well. This will allow monitoring the anemometer performance as well as comparing ice accretion on the moving blades to a motionless structure.

5. ICE THROW MONITORING

As the wind turbine is located close to ski slopes, ice throw is an important safety issue [4]. 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 (Fig. 5), collected in a data base.

During winter 2005/06, more than 100 ice fragments with a maximum length of more than 40 cm and a weight of up to 850 g could be recorded in distances of up to 92 m from the wind turbine (Fig. 6). Most likely, ice throw happened during or right after a blade heating process either when the ice slides along the blades towards the ground when the turbine stands still or when the ice is thrown off the blades when the wind turbine resumes power production. Therefore, the area around the tower and under the blades is the most dangerous place concerning ice throw.

The maximum distances and weights of the ice fragments found showed, that ice throw is an important safety issue at the Gütsch site. The monitoring will be continued during the winters 2006/07 and 2007/08.

Fig. 5: Ice fragments from the E-40 wind turbine.

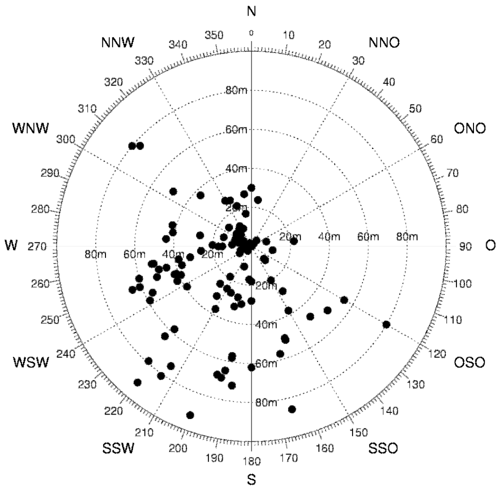

Fig. 6: Distribution of the ice throw around the wind turbine.

6. OPTIMIZING BLADE HEATING CONTROL

The wind turbine's blade heating is basically controlled by a comparison of the effective power production with the turbine's power curve. If icing is detected, the power production is stopped and the blades are heated with hot air for 90 minutes. Afterwards power production is resumed. Therefore, every heating process leads to a loss in power production.

The performance analysis during winter 2005/06 showed that this procedure is not capable of detecting light icing events (observed with use of the web cam's images). Furthermore, iced blades are not detected when wind speed is low. Therefore, it could happen that icing occurred at low wind speeds but was detected by the turbine only when the wind speed increased. The result was that the heating process took place during a high wind period and the loss in power production was higher than if the blade had been de-iced before.

In order to reduce the loss of power production due to blade heating, a simple approach for early ice detection will be tested during winter 2006/07: Icing conditions are defined as situations when the wind turbine's nacelle is in-cloud, the air temperature drops below 0°C and the relative humidity is higher than 95%. When these conditions are fulfilled, a SMS is automatically sent to the operator. With the web cam images, the operator can then check the state of the rotor blades and, based on this information, decide if a heating cycle should be initiated manually.

As air temperature and relative humidity may differ significantly between met station (2 m agl) and the nacelle of the wind turbine (50 m agl) [5, 6], an additional Rotronic MP101A temperature and humidity sensor was installed at the wind turbine. The measurement of in-cloud situations is achieved by an indirect method: A Kipp&Zonen CGR3 Pyrgeometer will be installed on the turbine's nacelle. With this instrument the incoming long wave radiation $L\downarrow$ is measured. Out of these values the sky temperature T_{Sky} can be derived according to Stefan-Boltzmann's law:

$$T_{Sky} = \sqrt[4]{\frac{L\downarrow}{\sigma}} - 273.15 \qquad [°C]$$
$$\sigma = 5.67 \cdot 10^{-8} Wm^{-2}K^{-4}$$

If the cloud base is higher than the wind turbine or there are no clouds at all, the sky temperature is significantly lower than the air temperature at hub height. If the sky temperature gets close to or is equal to the air temperature at hub height, there is a high probability that the nacelle is in-cloud (Fig. 7 and 8).

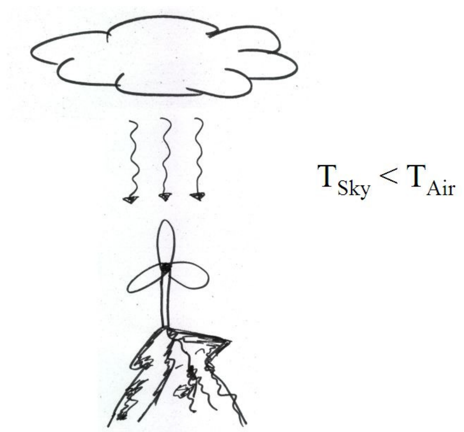

Fig. 7: When the cloud base is higher than the wind turbine's nacelle, the sky temperature is significantly lower than the air temperature at the nacelle.

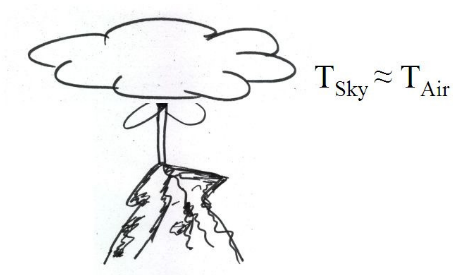

Fig. 8: When the sky temperature is approximately equal to the air temperature, there is a high probability that the wind turbine's nacelle is in-cloud.

7. CONCLUSIONS

The results of the wind turbine monitoring during the first project's winter 2005/6 led to the following conclusions:

- Visual observation of the rotor blades can be achieved effectively by use of a commercial web cam with motion detection.
- Visual observation is crucial for monitoring wind turbine performance under icing conditions.
- Ice throw is a significant safety risk at the Gütsch site.
- The most dangerous areas are near the tower and underneath the blades especially during und shortly after a blade heating process.
- Sometimes, not all of the ice could be removed from the blades during the heating process.
- Ice detection by comparison of effective power production and power curve works well for moderate to high wind speeds and moderate to heavy icing.
- A different approach is needed for detecting light icing or icing at low wind speeds in order to minimize losses in production by blade heating.
- Ice detection by a combination of meteorological measurements and visual observation of the rotor blades seems promising and will be tested.

6. ACKNOWLEDGEMENTS

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8. REFERENCES

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