Two years of icing monitoring at Nygårdsfjell Wind Park

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Abstract— Icing at Nygårdsfjell Wind Park was monitored for two winters (2007-08 and 2008-09) and production data during the same period was studied to determine production losses due to icing. The wind park consists of three 2.3 MW pitch controlled Siemens wind turbines, in northern Norway. The wind park is in mountainous terrain above tree line. Instrumentation consisted of standard wind turbine instrumentation, an optics based icing sensor on the nacelle, and two web cameras monitoring the blades and the other instruments. An evaluation of the icing sensor performance relative to the wind turbine production losses was performed. Experiences with the web cameras are also reported.

I. Introduction

Nygårdsfjell wind park, in northern Norway consists of three 2.3 MW pitch controlled Siemens wind turbines. The wind park is in mountainous terrain above tree line and is subject to atmospheric icing during the winter. Therefore instrumentation for monitoring the performance of the wind turbine was installed. Instrumentation consisted of standard wind turbine instrumentation, an optics based icing sensor on the nacelle, and two webcameras monitoring the blades and the other instruments. The icing monitoring described by Homola, et al [1] was without cameras.

II. Equipment description

The additional equipment for monitoring icing that was installed is described in this section together with the normal wind turbine instruments which were used for icing evaluation.

A. Web cameras

Two web cameras were installed during the 2007-08 winter. The brand and type chosen was Mobotix M22-Sec. This camera type has a range of built in functions that seemed to be suitable for this application. Some of these are; a weather proof housing, capability for a direct Ethernet connection, built in ftp function to transfer captured images to an ftp server, can store images to a shared folder on a computer on the local network, automatic motion detection function that can be used to trigger when pictures are taken and timer functions to take pictures at specified intervals.

Camera one was fitted with a 43 mm lens and set to take pictures of the tail area (anemometers) every 15 minutes. Camera two was fitted with a 65 mm lens and set to take pictures of the blades every 10 minutes when motion was detected.

Heat lamps were mounted on short booms to keep the cameras clear of ice during the winter. The operation of the heat lamps was simply that they were on all of the time. New bulbs were installed near the start of the icing season to ensure best possible operation during the winter. Figures 1 and 2 show the cameras installed on the wind turbines warning light boom. The camera was able to capture some images with icing clearly visible on the blades, and an example can be seen in figure 3.

Having adequate light for good quality pictures was a challenge, especially during the winter when the light period of each day is quite short and on the cloudy days when icing is of interest. Figure 4 illustrates the type of images from these kinds of periods. The camera automatically lengthens the image exposure time when there is less light, but this necessarily causes blurring of the moving blade. The motion detection seemed to be less reliable during darker periods, but as the image quality during such times was typically low that does not seem to be a major issue.

Fog or low clouds also disturb visibility in addition to absorbing light. And, as figure 5 shows, the image quality during foggy periods also suffers. Figure 5 was taken during a time period when the HoloOptics sensor was indicating ice accretion but this can not be confirmed from the image of the blade.

An additional challenge with the web cameras was in using the motion detection to capture images of the blades. The parameters were adjusted many times without resulting in consistent image captures of the blades. Finally it was found that the camera has too low of a frame rate for the motion detection software to work properly, when the camera resolution is set to the maximum. The problem could be solved by either using a wider angle lens or lowering the resolution, but both options would result in poorer images of the blades. Ultimately it was decided to increase the number of pictures taken to get enough good images.


Figure 1: Web cameras installed on light boom.

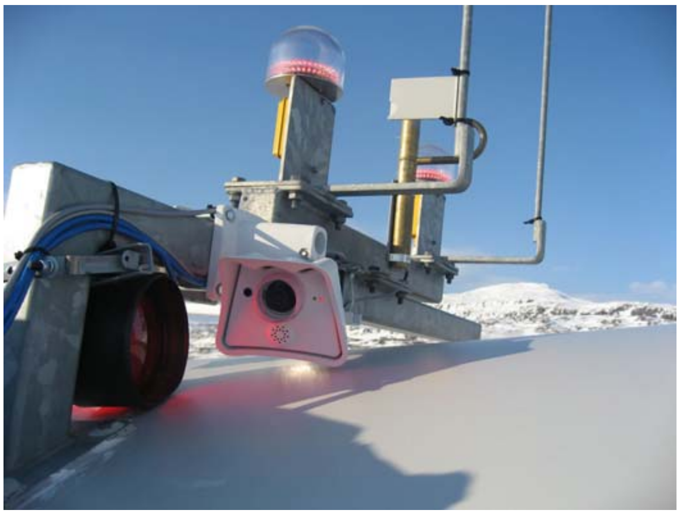


Figure 2: Web camera mounted on light boom.


Figure 3: Icing documented by web camera.


Figure 4: Icing indicated by HoloOptics, but there is too little light for the web camera to capture a clear image.


Figure 5: Icing indicated by HoloOptics, but fog and low light makes it impossible to detect icing visually.

B. *Ice Sensor*

A HoloOptics icing sensor was installed on one of the turbines on the same light boom as the cameras. The installed sensor is shown in figure 6.

Data acquisition was done with a direct connection to one of the pins on a serial port of a laptop computer, and a Labview script to read the status of the pin every three seconds and write it to a text file. This meant that the data files were larger than necessary, and perhaps it would have been better to only record the transitions between high and low. The laptop required a protective box to keep it warmer during the winter, so an insulated box with thermostat and a 60 W lamp for extra heating was constructed. This box also contained the power supply for the ice sensor and is shown in figure 7.

The ice sensor setup had no method for testing for correct operation. Therefore it was necessary to visit the site periodically and manually block the beam to determine if the ice sensor was working properly.

The HoloOptics ice sensor used here only used the detection of the reflected light beam to indicate ice or no-ice. This meant that rain can cause a false indication by disturbing the reflection. Therefore during data processing the temperature measurements from the wind turbine were used to ensure that only periods below 0.5 C would be indicated as icing.

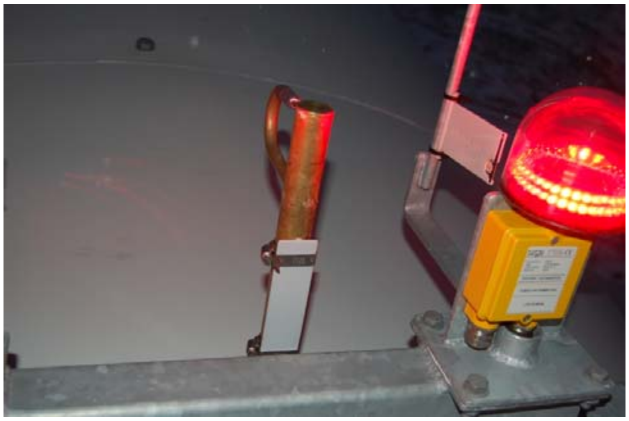


Figure 6: HoloOptics sensor installed on light boom.

Figure 7: Data logging PC and power supply for HoloOptics.

C. Wind and power measurements

Wind and power measurements were made through the wind turbines internal data acquisition system. For the winter of 2007-2008, the two anemometers used were NRG Icefree 3 and KK-electronics with an extra radiant heating spiral. During the spring of 2008, the NRG anemometers were replaced with sonic anemometers.

All of the anemometers have had some difficulties during the winter, but the combination of the KK and sonic anemometers seems overall to perform more consistently in icing and cold conditions then the combination of KK and NRG Icefree 3 anemometers had. It appears that turbine 573 in 07-08 had some problems, while 575 in 07-08 shows the least spread of any.

The ice sensor data was processed to generate an average for each 10 minute period, to correspond with the 10 minute periods of the wind turbines data system. Thereafter the two datasets were combined and the combination of icing indication and power losses were plotted together.

Figure 8 shows all the power production of the wind turbines plotted against the highest of the two anemometers as blue dots. Periods when power production appears abnormally high, more than 115% of the expected or mean power for the bin, is called overproduction, and can be seen as point above or to the left of the main swath of data points. These correspond to a high power production relative to the recorded wind speed and may indicate that the anemometers are iced or otherwise not operating correctly. The red dots on the figures are the periods when the HoloOptics sensor indicated icing and the temperature was below 0.5 C.

Though the figures do not show a perfect correlation between over or under production and icing indications, they do seem to show that icing indications occurred often during times with over or underproduction. The calculated power losses from the wind turbines are described in another paper at this conference, together with the calculation of overproduction and underproduction.

The correlation between an indication of icing and the turbine operating in an over or under production was calculated and is shown in Table 1. There it can be seen that the correlation is low, but slightly positive.

Table 1: Correlation between icing indication and over/under production

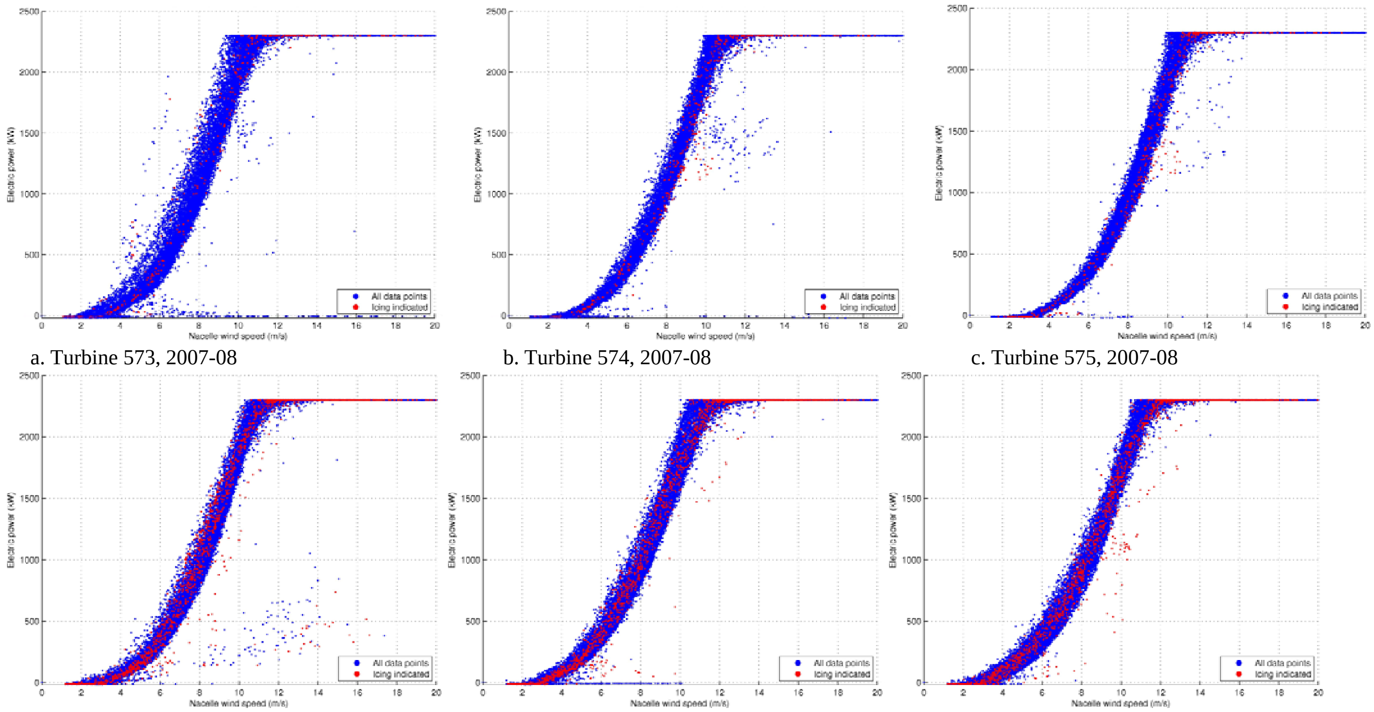
	573	**574**	**575**
2007-08	0.022	0.035	0.081
2008-09	0.127	0.041	0.046

III. Results and Discussion

Monitoring wind turbine performance under icing conditions has a few challenges.

Visibility is generally poor during icing conditions. Firstly because the icing itself results from water droplets in the air, fog, which reduce both visibility and light. Secondly daylight during the winter is much less than during the summer, especially with arctic sites such as Nygårdsfjell.

Neither the cameras or ice sensor come as ready kits for icing monitoring on wind turbines so a significant amount of time for planning and installing these items must be calculated for. One of the areas that took quite some time was the collecting and archiving of the data.



a. Turbine 573, 2007-08 b. Turbine 574, 2007-08 c. Turbine 575, 2007-08

d. Turbine 573, 2008-09 e. Turbine 574, 2008-09 f. Turbine 575, 2008-09

Figure 8: All turbine production data is shown in blue, and periods when icing was indicated by the HoloOptics sensor are shown in red.

The HoloOptics icing sensor does not appear to indicate all of the periods when power production deviates from the normal for the measured wind speed, but this can have several reasons. First, the icing sensor has a different geometry than both the anemometers and the turbine blades. Therefore ice can accumulate more or less on the different geometries due to their different collection efficiencies and relative wind speeds [2]. Second, the turbine blades operate in a range of altitudes, so they can encounter icing independently of the nacelle [3]. Finally, icing has both an accumulation period and a duration. Since the ice sensor automatically de-ices, it is expected to only show icing during the accumulation period. Thereafter ice can persist and continue to disturb the wind turbine operation for some time after the ice accumulation is over.

Further work could examine the timing of icing indications and production errors to determine how much of the mismatch between the two is due to the persistence of ice after an icing event.

Reliable anemometer operation is also critical to monitoring of a wind turbines performance and incorrect wind speeds are an issue at times here.

IV. Conclusions

Monitoring icing and its effects on wind turbines is not a trivial task. The experiences from Nygårdsfjell are that the low light and low visibility during times of typical icing make it difficult to use cameras for visual confirmation of icing.

The icing indications from the icing sensor used were only weakly correlated to periods when the wind turbine operation could be seen to be outside of the normal operational envelope. At least some of the lack of correlation can be understood by the anemometers not always operating correctly during icing conditions, and the differences in ice accretion on the different geometries.

V. Acknowledgment

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VI. References

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