Evaluation of Operational Data in respect to Production Losses due to Icing

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Abstract— **This contribution concentrates on the assessment of icing losses in operating wind farms. As an example, the production losses due to icing for 4 wind turbine sites located in Europe and Canada are assessed. These wind farms operate under different climatic conditions, are differently equipped with de-icing facilities and work under different operational management: with and without rotor blade heating; with stop under icing conditions to prevent extra loads or to prevent ice throw; or without stop under icing conditions. The production data of one winter season are assessed on a 10-minutes basis. The power curve related to the nacelle anemometer is assessed for the non-icing situations. The icing losses are evaluated based on the difference to this nacelle-anemometer power curve. Next to the evaluation of operational data of the wind farms, data of a parallel or former non-heated wind measurement are assessed for signs of icing.**

I. Introduction

MORE and more wind turbines are erected in alpine or northern regions, subjected to icing. As a consequence, the prediction of production losses due to icing becomes an essential issue.

Usually, an energy yield assessment is based on the wind data from an unheated or/and an ice-free anemometer, as well as, sometimes, on temperature and humidity measurements. Normally no ice sensor or further equipment is installed.

So far, the operational losses due to icing have only been evaluated for a few wind turbines sites, e.g. in [1].

II. Sites

As an example, the production losses due to icing for 4 wind turbine sites located in the Central Massive in France, in the Swiss Alps, in Austria and Canada are assessed.

Details of the 4 sites are given in the figures below and in the summary tables in section VII.

Fig. 1. 3 sites in Europe.

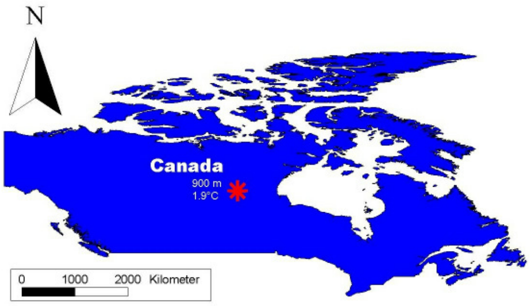


Fig. 2. Canadian Site.

III. France – Massif Central

The wind farm Castelnau-Pégayrols is located in the Central-Massif in South France. It consists of 13 wind turbines of the type Enercon E70 E4 and is located at a height level of about 1080 m a.s.l.. The wind farm went into operation just in the winter 2007/2008, so the production data is affected by the beginning of operation. Especially the wind turbines were temporarily running in a power limited operation mode.

The wind turbines were operated without rotor blade heating. Under icing conditions the wind turbines were stopped to prevent mechanical loads.

The period 11/2007- 04/2008 has been evaluated. In parallel a wind measurement with non-heated sensors is operated in the wind farm area. Periods with iced sensors have been identified by visual control. Icing signs were a frozen wind vane, stop of one or more anemometers or unrealistic low wind speeds (in comparison to other anemometers at the mast). On 26 days icing signs were detected. The total duration of icing situations was 336 hours which equates to 4% of a 1-years duration.

Three wind turbines (wt 11, 12 and 13) have been chosen for the evaluation. For each wind turbine the power curve related to the nacelle anemometer is assessed for the non-icing situations. A density correction for each data set has been performed before. Figure 3 shows as an example a plot of the power output above the wind speed at the nacelle anemometer. The following filtering processes have been performed. The data sets with parallel iced wind measurement have been filtered out, zero-values have been filtered out, a power filter [900;1100] and [1950;2100] has been set to consider the temporary power limitations. Additionally, outliners have been filtered out, when the power output differ more than one standard deviation from the remaining data set in the wind speed bin.

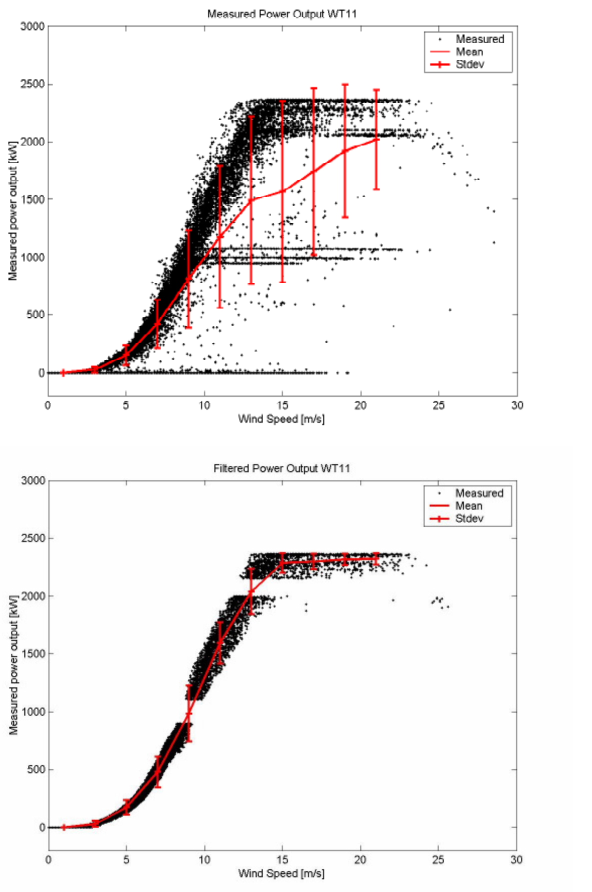


Fig. 3. French site: power output versus wind speed for wt11, all data (above) and after filtering (below).

Then the icing losses are evaluated based on the difference to this nacelle-anemometer power curve.

To identify the losses due to icing only the losses that occurred on days when icing occurred at the parallel wind measurement have been assigned as icing losses. These losses were 3% related to the predicted energy yield of a whole year.

There is a strong congruence between icing at the non-heated wind measurement and icing at the wind turbines at this site. The main icing losses occurred in January 2008. For January the periods with lower productions correspond clearly with the periods when icing occurred at the wind measurement. There were 5 icing periods: 3.1., 11.1-13.01. 16.1. , 22.1.-23.1. and 29.1.-31.01, each is visible in the production as well. The wind turbines were stopped each of these periods.

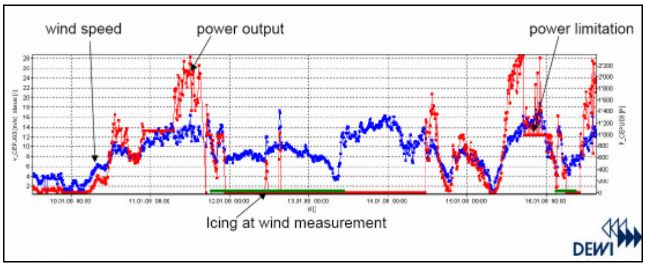


Fig. 4. French site: wt11, example for an icing period, wind speed, power output and icing status. The wind turbine stop persists longer than the ice at the parallel wind measurement.

IV. AUSTRIA-STERNWALD

The wind farm consists of 1 Vestas V80-2.0 MW and 6 Vestas V90-2.0 MW. The wind farm Sternwald is located in north-east Austria at the border to the Czech Republic at a height level of approximately 1000 m height a.s.l..

All wind turbines are equipped with ice detection “IGUS Blade Control”. This ice detection measures the natural frequency of the blades and detects a frequency shift when ice is on the blades.

When ice is detected the wind turbines are stopped. The machines are re-started automatically 30min after the first message that no ice is on the blades.

The power curve related to the nacelle anemometer is assessed for the non-icing situations. The month Feb. 2008 showed nearly no icing, therefore data from this month has been used to assess the power curve for each wt.

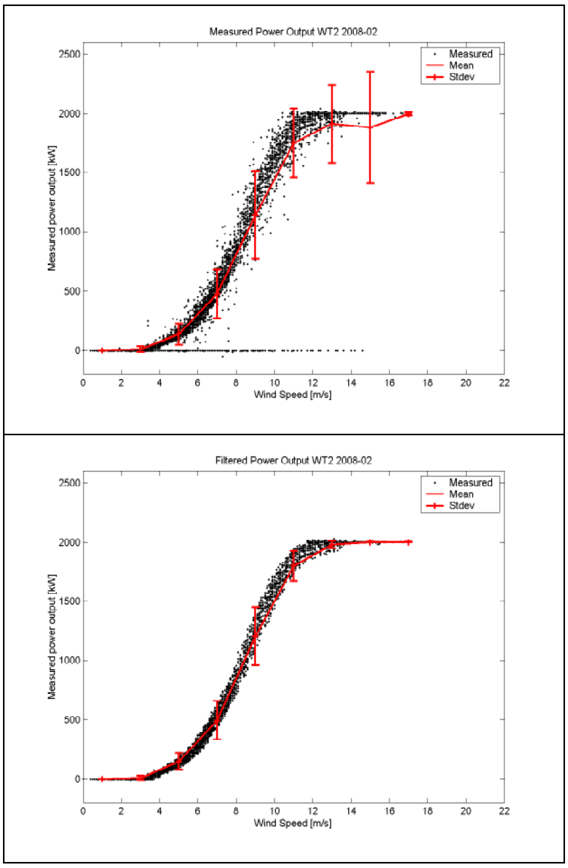


Fig. 5: Sternwald, wt2, Feb2008 data for non-icing situations, above all data, below after filtering.

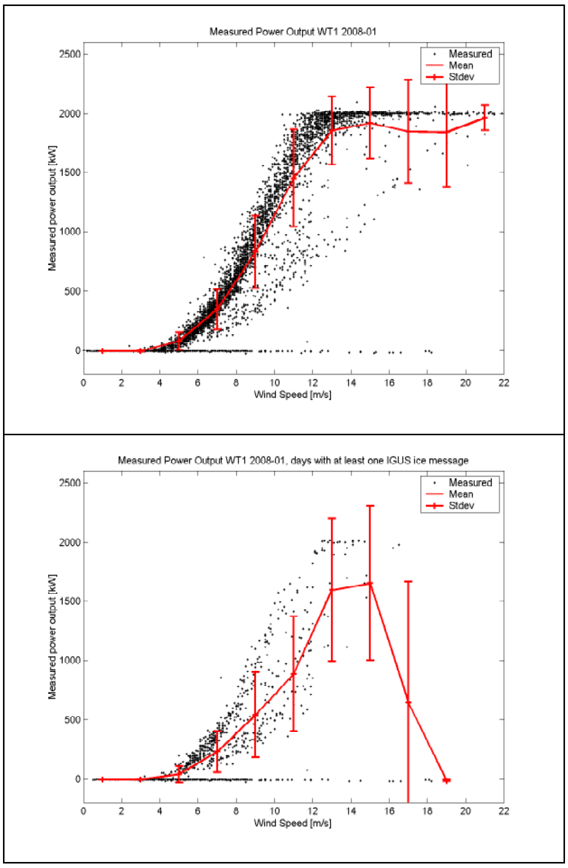


Fig. 6. Sternwald, wt1, Jan 2008, above: all data, below: data of the days when IGUS Blade Control detected ice.

The losses due to a stop of the wt's because of the status message "ice" have been assessed. They sum up to 9% related to the evaluated winter period or 4% related to the predicted AEP.

Additional, the losses due to stop or a reduced power output, which happens on days with at least one IGUS ice status message, have been assigned as icing losses, too. As an example Fig. 6 shows the power output of wt1 in January 2008 and the power output of the same wt only at the days with at least one IGUS ice status message. Together (data sets from days with at least one IGUS ice message) the losses sum up to 13% related to the evaluated winter period or 5% related to the predicted AEP.

Table 1 shows the icing losses related to the calculated production of each month, the evaluated winter period and the predicted AEP of a whole year.

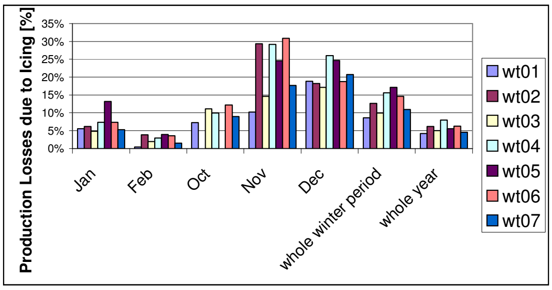


Table 1. Production losses due to icing as percentage of the calculated production, for each month, whole winter and related to predicted AEP.

V. Canadian Site

The wind farm is located in Canada at a height level of about 900 m. The wind turbines have no rotor blade heating and are operated without stopping for icing conditions. The evaluation period is 2005-08-01 – 2006-02-26.

There is a parallel wind measurement in 5 km distance at approximately the same height level. The parallel non-heated wind measurement was affected by icing during 38% of the evaluation time; that corresponds to 21.8% of a whole year.

The production data has been divided in two data sets for each wind turbine: with and without icing at the parallel wind measurement.

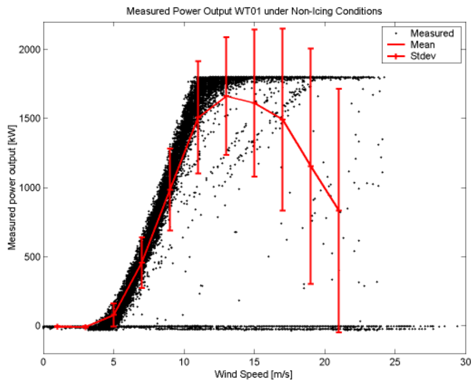


Fig. 7: Power output wt01 under non-icing conditions.

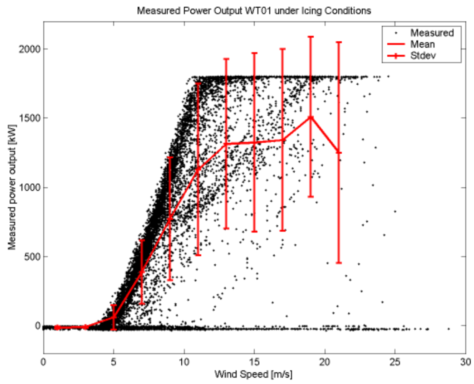


Fig. 8. Power output wt01 under icing conditions.

When icing occurs at the parallel wind measurement, in this example the power output is reduced for approximately 25%.

Production losses due to icing have been assessed to be 6% related to the power output of a whole year.

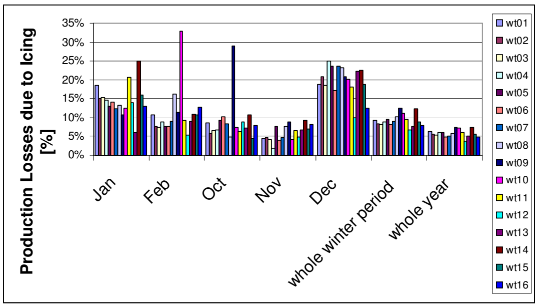


Table 2. Production losses due to icing as percentage of the calculated production, for each month, whole winter and related to predicted AEP.

VI. Swiss Alps - Guetsch

The wind turbine Guetsch Enercon E40-600kW is located in the Swiss Alps in 2332 m height a.s.l.. The wind turbine is operating since 2005 and equipped with rotor blade heating devices. The period 2007-06-01 – 2008-05-31 has been evaluated.

There was no parallel wind measurement with non-heated anemometers available. Icing periods have been identified by temperature measurement aside dew point temperature measurement, both measured at a station of MeteoSwiss nearby the wt.

The average temperature at the meteorological station Guetsch (height 2284 m a.s.l.) is 0.6°C. During the months 06, 07, 08/2007 and 05/2008 icing is negligible, temperature is almost always above 0°C. On 224 days the temperature was equal or below 0°C.

Icing periods have been identified as those with T<-1°C and |T-Tdew point |< 1°C. On 141 days this criterion was fulfilled. To identify the losses due to icing only the losses that occurred when the dew-point criterion was fulfilled have been assigned as icing losses. That was 4% related to the predicted energy yield of a whole year.

Additionally, data of the rotor blade heating have been evaluated. There were 127 heating cycles on 44 days. The losses at days with at least one heating cycle sum up to 4% related to the predicted AEP.

There is a high correlation but no complete correspondence between both evaluations Altogether the losses due to icing sum up to 5% related to the predicted AEP.

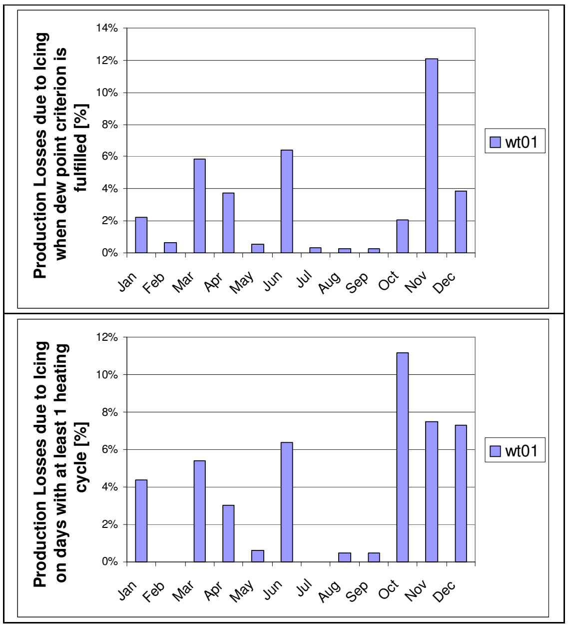
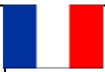
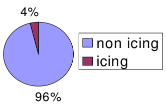
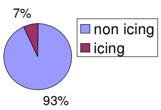


Fig. 9: Production losses due to icing above: when the dew point criterion is fulfilled, below on days with at least one heating cycle.

<table>
<tr><td>Site</td><td>
France
Castelnau-Pegayrols</td><td>
Austria
Sternwald</td></tr>
<tr><td>Rotor blade heating</td><td></td><td></td></tr>
<tr><td>Operation mode under icing conditions</td><td>Stop to prevent loads</td><td>Stop to prevent loads and to prevent ice throw</td></tr>
<tr><td>Evaluation time</td><td>2007/2008</td><td>2007/2008</td></tr>
<tr><td>Identification of icing situations</td><td>Parallel non-heated wind measurement</td><td>IGUS blade control</td></tr>
<tr><td>Approximate share of icing conditions</td><td>v: 4%
</td><td>IGUS:5%
v: 7%
</td></tr>
<tr><td>Approximate Icing losses</td><td>3%
</td><td>5%
</td></tr>
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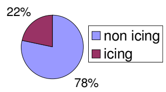
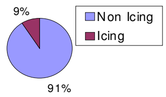
<table>
<tr><td>Site</td><td>
Canada</td><td>
Switzerland
Gütsch</td></tr>
<tr><td>Rotor blade heating</td><td></td><td></td></tr>
<tr><td>Operation mode under icing conditions</td><td>No stop under icing conditions</td><td>Stop during the heating cycle</td></tr>
<tr><td>Evaluation time</td><td>2005/2006</td><td>2007/2008</td></tr>
<tr><td>Identification of icing situations</td><td>Parallel heated and non-heated wind measurement</td><td>Dew-point criterion T<-1 °C; |T-Tdew point| <1 °C</td></tr>
<tr><td>Approximate share of icing conditions</td><td>v: 22%
</td><td>Dew-point criterion
9%
</td></tr>
<tr><td>Approximate Icing losses</td><td>6%
</td><td>5%
</td></tr>
</table>

VII. Results and Outlook

The tables above give an overview over the results. Even though this assessment is only valid for the assessed sites and periods it outlines possible effects of icing on wind farms operating under different climates and operational modes.

However, it is important to emphasise that the results cannot be assigned to other wind farms. For example at the Canada site ice persists at a non-heated anemometer for weeks and at the French site only for maximal a few days. Operational modus (stopping or not stopping) and requirements to prevent ice throw have large impact on the production losses.

The motivation of this evaluation was whether it is possible to detect icing losses from icing signs in wind measurements alone. The stronger the icing is at the site the less reliable is the assessment of wind measurements alone. Additionally data of temperature and humidity, dew point temperature or incoming long-wave temperature [2] should be gathered and evaluated. This applies especially for cold and northern sites, for which the ice sticks very long at structures.

VIII. Acknowledgements

We want to acknowledge the wind farm operators for making available the operational data and for further useful information.

IX. References

[1] B. Tammelin, K. Säntti, H. Dobesch, M. Durstewich, H. Ganander, G. Kury, T. Laakso, E. Peltola, G. Ronsten: "Wind Turbines in Icing Environment: Improvement of Tools for Siting, Certification and Operation – NEW ICETOOLS", Finnish Meteorological Institute, 2005, Helsinki, Finland.

[2] R. Cattin, S. Kunz, A. Heimo, M. Russi, G. Russi: "Two Years of Monitoring of a Wind Turbine unter Icing Conditions", proceedings of the DEWEK 2008, Bremen, November 2008