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Commissioning of a new ice-free anemometer: 2011 Field tests at WEICan

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ABSTRACT

The main objective of this article is to present the results gathered during the commissioning of a new ice-free cup anemometer developed at Université Laval. These tests took place at the Wind Energy Institute of Canada (WEICan) between January 2011 and April 2011, whereby icing events occurred and through the observations in this paper will show the need for ice-free anemometers in the wind industry in cold climates. Unbiased wind measurements cannot be obtained without ice-free anemometers. At such sites, the use of unheated wind speed sensors during the resource assessment phase leads to higher uncertainty of the wind speed. The use of properly heated anemometers can reduce wind speed measurement uncertainty, thus reducing financial uncertainty. A crude estimation of the financial losses based on the number of icing hours and the number of installed MW is also proposed. Caution should be exerted when choosing and installing ice-free instruments. Under specific conditions, improperly heated anemometers can lead to less accurate wind measurements than unheated anemometers. Wind turbines safe operation could be jeopardized with the use of improperly heated anemometers.

1. Introduction

In the actual socio-economic situation oriented toward sustainable development, wind energy stands out as a major source of alternative energy. The North American wind energy capacity has increased significantly over the last decade as shown in Fig. 1. According to “The Wind Power”[1] (a worldwide database with regards to wind turbines and wind farms), the installed capacity in North America went from 2701 MW in 2000 to 44208 MW in 2010.

An analysis of the spatial distribution of the wind farms installations over North America (see Fig. 2) shows that only 9% of the installed wind farms are located in Canada, leaving huge unexploited wind resources in Canadian territory. The wind potential over the province of Québec (see Natural Resources Ministry of the province of Quebec website[2]) indicates a great wind resource at northern latitudes where harsh climate prevails. The wind energy industry is still growing in Canada and it is foreseen that the total installed capacity will double in Canada within 6 years, going from 4008 MW in 2010 to 8700 MW in 2016 (source: www.thewindpower.net and www.canwea.ca). As more and more projects are commissioned, the new projects will tend to be installed further north where high wind potential is available but where there are also higher risks related to wind farm operation in cold climate. Wind speed measurement under icing conditions is already and will continue to be one of the challenges to be faced.

It is now a well known fact that the operation of wind energy related equipment (meteorological mast, wind

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[2] Gisement éolien du Québec par classe Battelle. URL: http://www.mrnf.gouv.qc.ca/publications/energie/eolien/densite_puissance_micro_65m_QC.pdf. [accessed: January 3rd, 2012] [archived by WebCite® at http://www.webcitation.org/64QM1BMnR].

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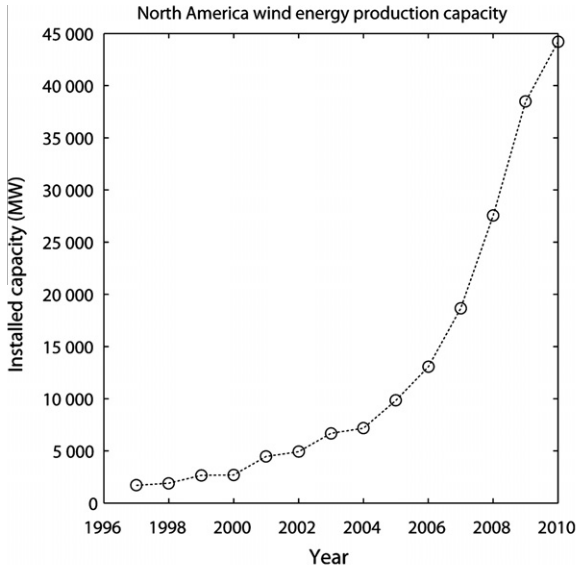

Fig. 1. North America wind energy production capacity.

turbines, etc.) in cold climate should be based on reliable, rugged and accurate measurement devices, especially anemometers. Makkonen et al. [1] showed that the accumulation of ice on anemometers leads to erroneous wind measurements. Wind measurements in cold climates are very challenging and under some circumstances anemometers may slow down or stop completely [2,3]. As a rule, heated sensors are recommended at sites with potential icing [2,3]. Since **no** sensor can stay ice free under all conditions [2], caution should be used while selecting and using such instruments. Early attempts in the 1970's at getting ice-free wind sensors are presented by Glidden [4], where 500 W external infrared lamps were installed to prevent the instrument from freezing. However, these somehow invasive setups disrupted the flow around the sensors leading to less accurate measurements. Tammelin et al. pointed out in 2001 [5] that several types of ice-free sensors were available on the market but that many were not accurate in icy conditions. The most commonly used commercially available ice-free cup anemometers are the IceFree3 (NRG systems) and the WAA252 (Vaisala), but they present several drawbacks. Fig. 3 presents the surface temperature distribution for both the Icefree3 and the WAA252 sensors in a refrigerated wind tunnel under a 10 m/s wind flow at $-10\,^{\circ}$C. Under these conditions, it is expected that both sensors operate at nominal power. From the thermal imaging, it is clear that there is a lack of heating on both instruments, especially the IceFree3. Even though the WAA252 instrument appears to be heated enough, reports [6] and private communications with wind developers [7] revealed that broken instruments due to icing were not uncommon. On the other hand, the sturdy IceFree3 built with an all aluminum rotor can withstand continuous operation in harsh environment but exhibit poor aerodynamic properties (e.g. off-axis response) as studied earlier [8]. Another heated cup anemometer well documented in the literature is the Hydro-Tech WS3 equipped with a 1.5 kW heater, that was used by Makkonen et al. [1]. No problems related to icing were encountered except in a few cases where the heating system had failed, for instance due to damage by lightning. However, the sturdy design of this instrument does have drawbacks such as a slow dynamic response due to a high distance constant, a high starting threshold, high overspeeding error due to the off-axis response of the instrument [9] leading to less accurate measurements and finally high power consumption. Cold climate locations are defined by *IEA Wind R&D Task 19*[3] as: "Sites at which significant icing events or periods with temperatures lower than the operational limits of standard wind turbines may occur." Accurate wind speed measurements are critical both during site assessment and for turbine operation. In a cold climate, the use of unheated wind speed sensors during the resource assessment phase may lead to an underestimation of the wind speed. As it is shown in this paper, using a properly heated anemometer during site assessment can help reduce wind speed measurement uncertainty and thus reduce financial uncertainty of a project. Coupled with a properly working ice detector, production losses due to icing can be estimated and the financial risk lowered. During turbine operation, the use of a non-heated wind speed sensor will cause the turbine not to start if wind speed measurements are below cut-in even if power could have been produced. Inaccurate wind speed information used by the turbine controller may result in non-optimal or even dangerous turbine operation. A heated anemometer could significantly improve power output and financial gains for wind energy installations in cold climates. If coupled with an ice detector and/or deicing techniques the benefits could be increased.

It is also worth mentioning that several studies comparing different sensors were done over the past decade. However, these studies focussed more on the testing of existing instruments rather than on the design of new sensors [10,5,11,6,12–14]. These challenges, in conjunction with the ever increasing installed wind energy capacity in North America, led to the development and commissioning of new ice-free wind sensors. Three ice-free cup anemometer prototypes were developed as part of a broad research program focusing on the design of ice-free sensors suited for the wind energy applications. The wanted features for such instruments are a good dynamic response, good off-axis response, high heating power, appropriate heating and low energy consumption in order to address the issues encountered with commercially available ice-free cup anemometers. No cup anemometer commercially available addresses all these issues; each of the available instruments addresses some of these issues as stated earlier. In order to gain a better understanding of the instruments behavior, these prototypes were tested under controlled conditions in both an icing climatic simulation chamber [15] and in a refrigerated wind tunnel. Some aerodynamic testing was done [8] and improvements were made on the aerodynamic and thermal behavior of the instrument so that it could stay ice-free under all simulated conditions. It was

[3] Wind Energy in Cold Climates. URL: http://www.arcticwind.vtt.fi/ [accessed: January 3rd, 2012] [archived by WebCite® at http://www.webcitation.org/64QMIL6uz].