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Met mast configuration and choice of sensors in cold climate conditions

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ABSTRACT

The installation and maintenance of broken sensors, in cold climate are significantly complicated. This study aims to serve as guide of best practices for increasing life-cycle, operational availability and data quality of sensors specifically in cold climates. The cold climate affects specifically the performance of the sensors. This makes very difficult the operation of met mast in cold climate and transforms it into a real challenge. Also, the cold climate induces various meteorological conditions: icing, low-temperature. The icing accumulation generates ice throw. These ice throw can break the sensors, and reduce the data availability. As well, icing events cause the degradation of the quality of measurement values. In this study, we focus about the causes of the sensor malfunctioning and the characteristics of each sensor. At the end, this study recommends met mast configuration and choice of sensors to increase their life-cycle and data availability in cold climate.

1. Introduction

Icing is a crucial factor for structural design in cold climate (CC) regions [1,2]. This climate is defined when one of these two conditions is met: low temperature climate (LTC) and icing climate (IC). LTC is set when temperature is below −20 °C more than 9 days during a year or when the annual air temperature is below 0 °C [3]. IC is defined when an instrumental icing, meteorological is detected on the site and induce a power loss on wind turbine [4]. Specifically for IC, the icing can represent a power loss more than 25% on the annual energy production (AEP). For IC site, the instrumentations are important for wind energy development phase to assess correctly the future wind farms. Many technologies and methods exist to determine the overall atmospheric boundary conditions over a terrain chosen to install a wind farm [5]. To achieve this study, the wind assessment needs the installation of met mast. This technology permit the installation of many different types of meteorological sensors (barometer, thermometer, ultrasonic anemometer, icing detection, wind vane, etc.) over all the atmospheric boundary layer. Foder [6] shows that the sensors in the CC is subjected to various meteorological conditions: storms, rain, ice and snow. These meteorological conditions produce measurement challenges for sensors. They include the meteorological measurements for synoptic and numerical weather prediction models. Icing events decrease the quality of measurement and sometimes, the destruction of the sensor itself. The World Meteorological Organization (WMO) has published the Guide to Meteorological Instruments and Methods of Observations for various instruments used for automatic weather stations [7]. To increase the data availability, Heimo et al. [8] propose a method to classify instruments in terms of icing sensitivity based on the characteristics of the operational site. The causes of the sensor malfunctioning can be the material properties [9]. The sensitivity of sensor in CC is a function of materials used in its fabrication. For example, Aluminum gets stronger at cold temperatures and is often preferable for cold weather situations [9]. As well other materials can be altered to be used in cold weather temperatures [6,10]. The strength of material increases as the material gets colder. In this study, the sensor breakage is compared based on the material which it is fabricated. The sensors material must have winter properties if it used in CC in

Abbreviations: AEP, annual energy production; a.g.l., above ground level; a.s.l., above sea level; BD, base dimension; CC, cold climate; FIA, Falling Ice Area; IC, icing climate; IEC, International Electrical Commission; LTC, low temperature climate; OF, overhang factor; MMV, met mast; R&D, research and development; SA, swept area; TCE, TechnoCentre Éolien; TMV, met mast.

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order to reduce wear and breakage related to this season. If freezing temperature below occurs only for short periods of time, sensors with cold climate properties may be ignored. However, if longer periods of freezing temperatures are encountered every year, then a sensor with cold climate properties is essential [10]. In order, this paper presents recommendations about met mast configuration for wind energy purpose and choice of sensors used in CC.

The Section 2 presents the description of the infrastructures use to calculate the statistics of breakages who are categorized following the Section 3. The Sections 4-6 of this article focus on three main topics as shown in Fig. 1 and described as follow:

A. Booms configuration (in blue), Section 4
B. Choice of sensor in CC against ice falling breakage (in green), Section 5
C. Choice of sensor in CC against icing effect on the measure (in red), Section 6

At the end of the article, the Sections 7 and 8 described the recommendations applicable for met mast in CC following analysis performed in previous section and future works in goal to improve the knowledge of this topic.

2. Location and description of met masts

This study performs analysis over data and maintenance records provided from four met masts (Table 1). All met masts of TCE is located at Gaspe Peninsula region in Quebec province (Canada). The sites are classified as complex terrain with high turbulence. The temperature varies from −40 to +30 °C.

Both sites are conformed to the CC definition [11]. All met masts are equipped with air temperature, humidity, pressure and wind (speed & direction) sensors at many levels (from the bottom to the top). Table 1 shows the list of overall sensors installed on met masts. Following the definition in Section 4.2.2, TMV2 (and MMV1 are configured with minimal risk and TMV3, MMV2 with maximal risk of icing failing on the booms. Fig. 2 shows a met mast configuration of 126 m height for research and development purpose, especially designed for CC (see Figs. 3 and 4).

3. Breakage recorded for each met masts by category

A maintenance log book records each failure/breakage of sensors installed on met masts. Each failure/breakage is classified according to 4 types:

- falling ice;
- ice accumulation;
- sensor choice;
- other.

Anemometers and thermometers are calibrated and installed in according to the standard [12]. By example, cameras, cup anemometers and vertical anemometer have a percentage of breakage more than 100% for all categories of breakage. This statistic means that the same sensor can break or fail many times during its life cycle in cold climate.

4. Boom configurations

In order to increase the data availability and decrease the number of breakage of sensors, many characteristics of the boom can be modified on a met mast: boom length, boom direction, boom heating and boom installation on the met mast. To assess the performance of each of these characteristics of the boom, we need to calculate and analyse the statistics of breakage caused by ice throw. After, we present three booms configuration to assess wind in CC in goal to minimize the sensors broken due ice falling.

4.1. Analysis of broken sensors by ice throw

Table 2 shows the sensors broken due to the ice falling. For all infrastructures, the statistics is compiled since the commissioning of the met mast until May-2015. The percentage of ice throw breakage is the ratio of the number of ice throw breakage divided by the number of sensors. When the ratio is over 100%, it means that a sensor breaks more than 2 times during the servicing lift of itself. Also, we want highlight few statistics from Table 2:

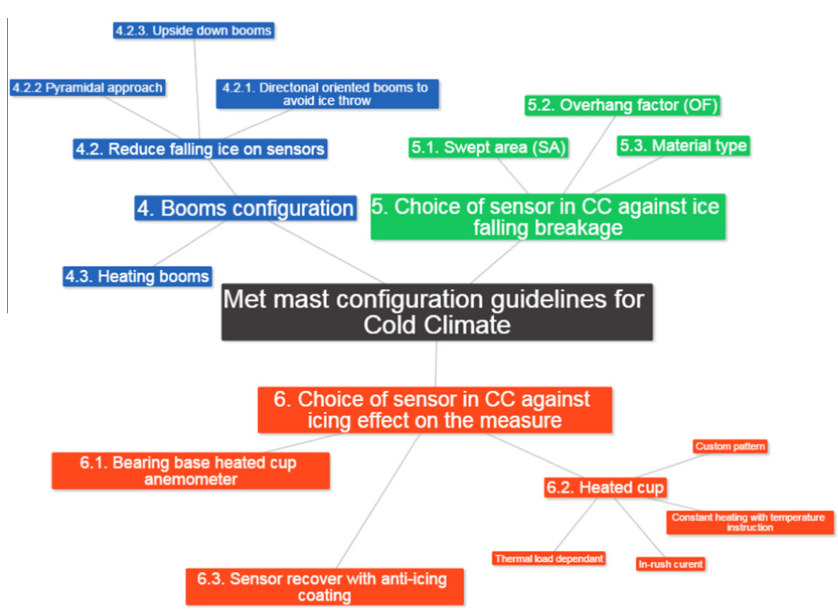

Fig. 1. Topics for met mast configuration guidleines in CC.