SPECIFIC RECOMMENDATIONS FOR THE DEVELOPMENT OF WIND ENERGY PROJECTS IN COLD CLIMATES

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ABSTRACT

International Energy Agency (IEA) R&D Wind started Annex XIX; Wind Energy in Cold Climates, in 2002. Wind energy in cold climates refers to sites that experience either icing events or low temperatures outside the operational limits of standard wind turbines. This international collaboration has gathered information about wind turbine operation in icy and low temperature environments in the participating countries Finland, Sweden, Norway, Switzerland, USA and Canada. The reliability of standards and adapted wind technology has been monitored. The goal of the annex is to establish recommendations for applying wind power in cold climates. Currently, cold climate is, however, often considered a synonym of uncertainty. As the "Market" dislikes uncertainties, it will penalize projects of wind farms in cold climates by higher interest rates and shorter repayment time. Consequently, the recommendations are intended to guide wind energy developers to a position where uncertainties related to cold climate issues are reduced to a minimum. The work is under way and the recommendations are planned to be published by the end of 2004. A summary of the current state of cold climate wind energy technology and recommendations are presented in the paper.

Keywords: Project Planning, Icing, Low temperature, Operational experience, and Recommended practices.

INTRODUCTION

Wind turbines may be located at sites where they are exposed to either icing or low temperatures, conditions that are outside the standard design limits of standard wind turbines. The consequences will be considerable production losses and unforeseen load cases which will cause financial losses and risk of premature mechanical failure. Some 500MW of installed capacity can be defined to be located at cold climate sites. Typically, cold climate sites are located at higher elevation compared to the surrounding landscape e.g. on mountain ridges or in valleys, which also provide favourable wind conditions. Places that can be easily classified as cold climate sites can be found in elevated areas in Scandinavia, North America, Europe and Asia.

Considering the vast energy production potential at cold climate sites it is likely that future wind energy projects to an increasingly extent will be implemented here. The economics of such projects have become more competitive, in relation to coastal and low land projects, due to increased experience, knowledge and improvements in cold climate technology.

BACKGROUND

IEA R&D Wind is an agreement between 19 countries and the European Commission to follow international development on wind energy deployment and to stimulate co-operative research and development of wind technology. The co-operation takes places in form of Annexes to the main agreement. The R&D-projects are usually task shared and only the coordination costs of the operating agent are shared. At present the following Annexes and their operating agents are

Tasks	**Topic**	**Operating agent**
XI	Wind technology information exchange	FOI, Sweden
XVI	Round robin test program	NREL, U.S
XVII	Database on wind characteristics	Riso, Denmark
XIX	Wind Energy in Cold Climates	VTT, Finland
XX	HAWT Aerodynamics and Models from Wind Tunnel Measurements	NREL, USA
XXI	Dynamic Models of Wind Farms for Power System Studies	Sintef, Norway

In 2001, International Energy Agency (IEA) R&D Wind started Annex XIX; "Wind Energy in Cold Climates". The operating agent of the annex is Technical Research Centre of Finland VTT and the participating institutes are FOI/FFA (Sweden), Kjeller Vindteknikk (Norway), NREL (USA), ENCO (Switzerland) and Natural Resources (Canada). The ongoing project is the first transatlantic cooperation in this field.

Ever since the start-up, the participants of Annex XIX have been collecting operational experiences from selected sites that experience frequent atmospheric icing or low temperatures. "Low temperature" is, in this context, defined to be below the operational limits of standard wind turbines. Collected data include information on performance of standard wind turbines as well as performance of adapted wind turbine technology specifically developed for cold climate sites. The collected data was evaluated and a report was written and published in the spring of 2003, [1]. The report can be downloaded from the Annex XIX web-site: http:\\arcticwind.vtt.fi.

The goal of Annex XIX is to collate information on available adapted wind turbine technology and to formulate recommended practices for project developers. These will enable improvements of the overall economy of wind energy projects and lower the risks involved in areas where low temperatures and atmospheric icing are frequent.

Expected results of the project can be summarised as:

- Reviewed experiences of building, installing and operating wind turbines at cold climate sites
- A method for assessing effects of low temperature and icing climates
- A Tool for estimation of project feasibility including adapted technical solutions
- A site-classification procedure for feasibility studies.
- Guidelines for developing wind energy in cold climate conditions.

COLD CLIMATE TECHNOLOGY

Ice detectors

Several methods and sensors to detect ice are available. This is due to the fact that atmospheric icing has been the subject of serious research in the aviation industry for years. In spite of this, there exist no transcendent, or even acceptable, solutions suited for icing measurements related to wind energy. One reason is that traditional ice detectors have been designed and optimized for aviation purposes, which implies higher air speeds. Another obstacle is the high cost presently associated with detecting ice on a wind turbine blade. However, the relative cost of ice detection is likely to be reduced in the near future, as wind energy projects grow bigger. Almost 10 years after the first projects were initiated, ice detectors with improved accuracy, i.e. calibrated properties, are still needed. Indirect methods to measure ice have been employed as well. The two most popular are humidity measurements and wind speed measurement with two anemometers of which one is properly heated, [2,3,4,5].

One new promising ice detector for wind energy applications is presented in **Figure 1**. An example of results is presented in **Figure 2**. The device is capable to measure both, duration of ice accretion phase as well as time which ice will be present on a structure.

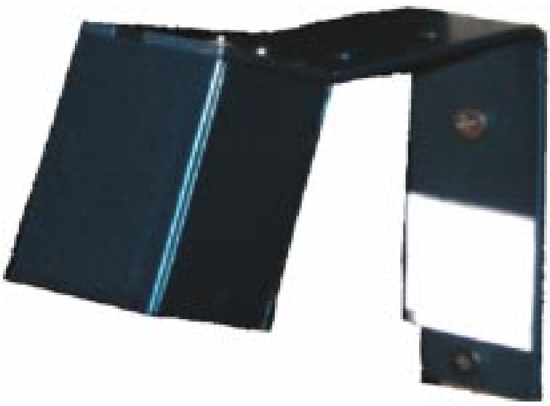

Figure 1. Present design of HoloOptics ice detector T23**.**

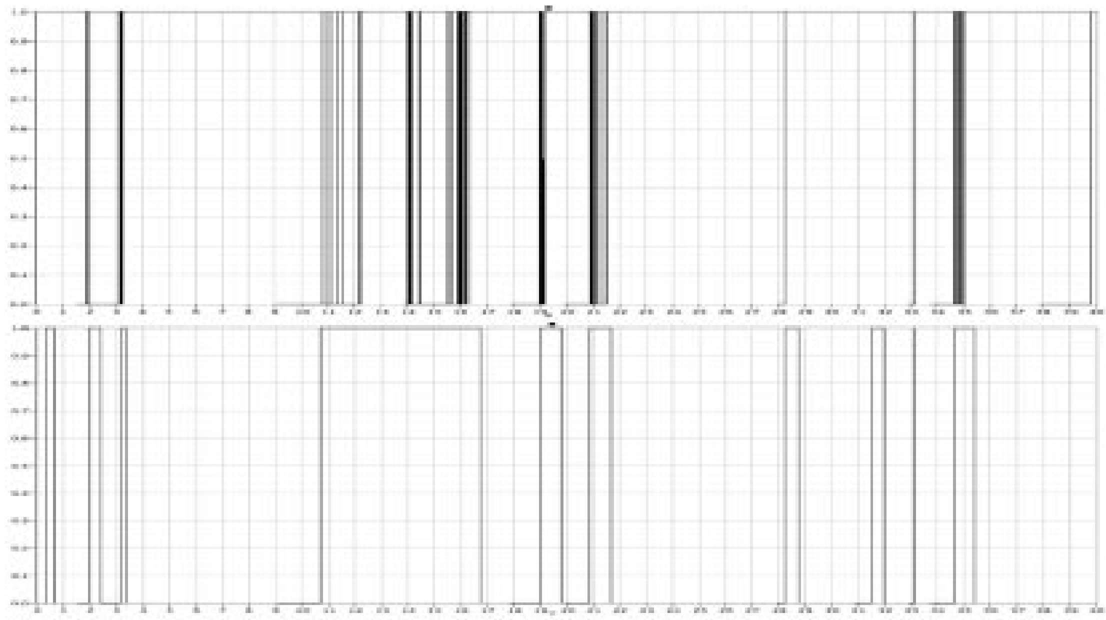

Figure 2. Ice detected by prototype versions of heated and unheated HoloOptics ice detector mounted on the nacelle of a Bonus 600 kW Mk IV in Suorva. 40 days are shown starting at 2003-12-21.

Anti and de-icing technology

Solutions for serious icing climate are on a prototype level. Some manufacturers offer commercial solutions for moderate icing climate, but no proven track records exist, [6,7].

Low temperature solutions

Technical solutions for low temperatures are readily available, as many wind turbine manufacturers have developed low temperature versions of their standard turbines. Consequently, low operating temperatures have been taken into account in the design of the turbines. In practice, this means selecting, often more costly, materials, gaskets, and lubricants capable to withstand low temperatures. Low temperature adaptations of wind turbines are based on proven and tested technologies from other fields of engineering. As a result, low temperatures have not caused major problems in recent years, [8].

Wind sensors

Low temperature and icing climates constitute additional challenges for wind resource measurements. A number of manufacturers of anemometers provide anemometer models with heating. Ultrasonic anemometers have yet to be further developed in order to be able to compete with the reliability of cup anemometers. Extensive research has been carried out in this field and devices suitable for wind resource estimation in severe icing climate are available, [9,10].

RECOMMENDATIONS

Wind energy in cold climates will in the near future, considering the large energy production potential and assuming that sufficient development resources are allocated to decrease the associated risks, occupy a large industry worldwide. The development of this sector has not, during the past 10 years, met the original high expectations anticipated by the manufacturers in the early 1990:s. There are two main reasons for this; other wind energy markets have been easier to conquer and the challenges associated with utilizing wind energy in cold and icy climates, often accompanied by complex terrain, has been difficult to master cost effectively.

The wind resource can often be estimated based on theoretical models, but actual wind speed measurements are most often needed, in fact always recommended, in order to decrease the uncertainties to acceptable levels. Consequently, these recommendations are intended to guide wind energy developers to a position where uncertainties related to cold climate issues are reduced to a minimum. The goal is to define internationally accepted recommendations that will cover the following topics:

- Site considerations
- Site measurements
- Project design and economics
- Project construction
- System operation
- Decomissioning

Site considerations
It is of outmost importance to recognise the possible effects of cold climate issues at an early stage of a project. Site accessibility, annual temperature variations and safety, both labour and public, are among the issues that need to be considered well in advance. A need of special transportation such as skidoos, bulldozers that enable access to a site during the winter months should be noticed in the project planning phase.

Site measurement
The importance of site measurements in connection to resource assessment of cold climate site cannot be overemphasised. Cold climate sites are often located in remote areas where usually only limited access is available. The limited access and the possibility of rapid weather changes must be noticed when planning the measurements. Power supply for heated instruments may require special solutions such as a mobile power plant and/or wind chargers and battery banks. Heated instruments should be used at sites where icing is likely. Site measurements must be able to provide not only wind information but also the severity of the local climate, i.e. estimation of the time that ice is present on structures as well as the temperature distribution. Two parallel methods to detect icing are advisable, because lots of uncertainties are related to performance of different ice detection methods, [2,3,4,5].

Project design and economics
The temperature distribution (in time) and the ice climate will impact the energy production. Therefore, technology selections should be based on the analysis of measurements. The profitability of de- and anti-icing systems needs to be calculated taking the capability of technology and climatic circumstances into account. This is due to the fact that already a thin layer of ice is capable of reducing performance by some 30%. The only commercially available heating system (Enercon) is presently not adequate for severe ice climates, [11].

Project construction
The time window for construction at a cold climate site may be considerably shorter compared with ditto in milder climates. Often, the time of the year dictates the construction time. Due to difficult locations or high altitudes, access for heavy cranes may be limited. Bulldozers or even helicopters may be needed for transportation of components and lifting. As the wildlife of cold climate sites might be sensitive, construction shall be planned such that the intentional environmental impact will be reduced to a minimum.

System operation
The normal operation of wind turbines adapted for cold climate conditions does not differ much from the operation of wind turbines that are located in a mild climate. The main differences are related to access to the site and working conditions during the cold period of time. Working is, in general, more time consuming in a cold environment. However, carrying out normal maintenance of wind turbines at a cold climate site is possible if regular bi-annual maintenance visits are scheduled to take place when climatic conditions are as good as possible. Heated work premises as well as a basic toolkit should be available for convenience and safety of maintenance staff in remote locations. This will also shorten the time needed for repairing of unexpected faults, [6,8].

Decommissioning
The revival of wildlife might take significant time at cold climate sites. Careful planning is thus needed to minimize the impact caused by decommissioning. Such planning, as well as advance payment or deposit, is often required by the licensing authorities.

SUMMARY

A vast wind energy potential exists at, often elevated, cold climate sites around the globe. Furthermore, as wind turbines tend to grow in size, icing is expected to become a major energy production design parameter in low land areas in northern regions as well.

Adapted technology for milder icing climates and low temperatures is readily available. However, there is still a need for the development of technology that can meet the requirements of the serious icing climates that prevail in parts of Europe, Asia and North America.

The importance of site measurements in connection to resource assessment of cold climate site cannot be overemphasised. A resource estimation, including an estimation of the impact of icing on production, is needed as a basis for a possible investment in cold climates. Otherwise, the uncertainty regarding production estimates might be unacceptably high.

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