NEW ICETOOLS - Experimental Wind Energy Data from Cold Climate Sites in Europe

B. Tammelin, Finnish Meteorological Institute (FI)

1. Introduction

There is a growing interest in EU to build wind power plants at inland sites and especially within mountainous regions, and also in the far north. Typical for such sites are not only low air temperature but also icing of blades and other components. These climate conditions make new requirements to design of wind turbines and their components, and also to wind power assessment and wind measurements, and to economical optimisation.

From the previous EU projects and some national projects there are quite a lot of theoretical and even some experimental data on wind turbines operating under such climatic and weather conditions. There have also been some improvements in producing ice-free wind sensors for wind energy assessment and operation of turbines, blade heating systems and codes to estimate loads and power production under icing conditions. However, it seems that wind turbine and component industry, and operators are poorly aware about occurrence and frequency of icing periods in various parts of Europe, not only in far North but also in most southern parts. There also seems to be a lack in knowledge of technical solutions already available, experiences in operation of different types of turbines under icing conditions, and also about safety problems caused especially through iced blades.

Fig. 1: A photomontage of 13 MW Tauernwindpark in Austria with Vestas wind turbines to be erected in 2002.

Within this project the aim is to collect systematically data from different types of wind power plants operated in different parts of Europe under different types of icing climate. Data will also be used to verify the codes available and improve the tools to predict loads, power production, heating demand on blades and other components.

2. The Project

2.1 Objectives and General Setting

The overall objectives of the project are to develop and improve the tools suitable for manufacturers, operators, developers and consultants to exploit wind energy utilisation in hostile terrain and ice-endangered sites (mountainous southern and Central Europe, arctic hills and valleys, Alps, northern European coast and off-shore).

Several wind turbines have already been installed at ice affected cold climate sites with very poor information on climatic conditions and needs for specially designed turbines, which has led to unsatisfactory and uneconomical wind power production. Some sites also produce safety problems for the public.

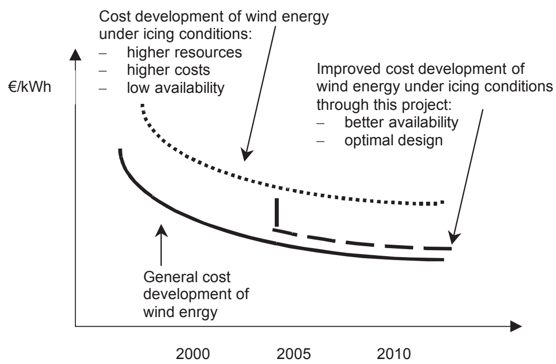

Fig. 2: Cost development of wind energy at lowland and icing sites. Due to the presented project some barriers hampering cold climate wind deployment will be overcome. As the reliability and availability of adapted technology can be verified and an optimal site-dependent design can be used, the net economics will respond to that of lowland applications.

There is a rapidly increasing interest in deploying wind energy under these harsh conditions not only within Europe but also elsewhere because the wind resource is extremely good. Icing, however, reduces the production yield and lowers the availability. Thus the economics of the project is worse than for normal lowland applications. Although adapted technology is developed, the anticipated high extra costs and the low confidence in ice-preventing technology hamper development. By this project, the net economics (expressed in €/kWh) of icing wind energy applications is expected to close the gap to that of normal lowland applications as described in the following figure. The results of the project will also improve the exploitation of inland sites with a more moderate wind resource.

2.2 Organisation

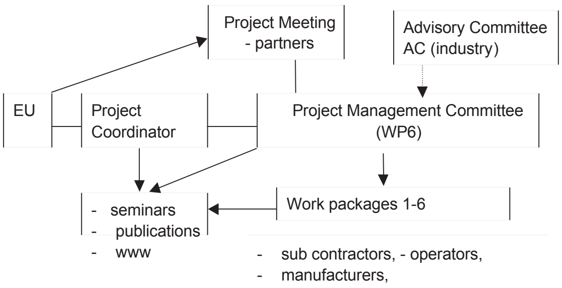

Fig. 3: New Icetools project management.

To achieve the overall objective the project is divided in six work packages. The work packages and their objectives are described in the 2.3.

The consortium includes 6 partners from Austria, Germany, Sweden and Finland. The general setting of the project is shown in Fig. 3. The project is coordinated by Finnish Meteorological Institute (FMI). An advisory committee having members from the industry and certifying bodies (DEWI and TÜV) is formed to guide the work of the project management committee.

In this way the project constitutes a co-ordinated effort to collate operational experiences from several wind energy installations under harsh climatic conditions with direct link to the industry and certifying bodies.

2.3 Work Programme

The project is divided into six work packages as shown in Table 1.

Work package No	Work package title
1	Icing
2	On-site icing and loss of production
3	Modelling ice loads
4	Prevention of icing effects
5	Questionnaire and market analyses
6	Management and information dissemination

In WP 1, coordinated by Finnish Meteorological Institute, the objective is to improve the knowledge on icing by

- collecting data of on-site measurements of icing
- verifying existing methods to estimate icing with observation performed at the WT and other sites in various parts of Europe
- studying the effect of solar radiation and temperature on duration of ice accumulation
- studying the meteorological / climatological conditions for icing
- studying the possibilities of icing forecast on the basis of regular meteorological products.

WP 2 is coordinated by ISET. The objectives are

- to study duration of ice accumulation on blades versus weather parameters using monitoring data produced in WP1
- to study the existing empirical data on icing events by analysing frequency, duration, failures, costs, energy loss, site characteristics at wind power plants
- to study the behaviour and requirements of nacelle-ice-free-anemometers
- to perform on-site intensive observation campaigns to verify the shape and amount of ice accumulated on the blades to verify:
- existing codes used to describe the ice on the blades to produce e.g. the Cl, Cd coefficients and to optimise the blade heating systems
- observed power curves to predicted power curves for stall and pitch controlled turbines
- to improve the PROP code for practical predictions of power curves and losses in power production, but also taking into account possible overproduction due to clear ice on the blades to improve the tool/method to predict power losses due to icing in various types of icing conditions upon stall and pitch controlled turbines
- ice accretion during idling upon blades of pitch and stall regulated turbines
- to calculate the effect and economics of blade heating systems, of stand stills due to safety problems and of potential anemometer problems on power production at several sites in Europe
- to study high air density versus high wind speed statistics in Europe
- to study the statistics between temperature, wind speed and solar radiation

In WP 3 VTT together with FOI aim to present and verify simple structural safety load cases for wind turbines operating under arctic conditions

WP 4, coordinated by VTT, deals the various methods to prevent the effects of icing. The objectives are

- to improve observation tools for icing events.
- to collate operational experience of wind turbines with blade heating in different types of icing climate.
- To collate information on blade heating influence, on lightning susceptibility, blade materials and aerodynamics.
- to study the durability and reliability of adapted technology

In WP 5 the aim is

- to collect feedback from the operators concerning their experience on icing events, cold climate problems and ice throw etc. For this a questionnaire will be sent to operators, manufacturers etc. to collect data from the winter 2002/2003.
- to produce a market study in wind potential at cold climate sites in EU including also the new candidate states

This work package is led by Enairgy.

The management as well as the information dissemination of the project is made in WP 6, coordinated by FMI.

2.4 Data Used in the Project

Much of the work is relying on past and ongoing measurement campaigns at several sites located in Austria, Germany, Sweden and Finland. Most of the data acquisition systems, which will be used in the project are already installed at operating power plants and thus this is a cost effective way to carry out joint measurement campaigns with comparable procedures and with common objectives.

Olostunturi, Finland

Olos is one of the most Northern wind farms in the world and it is operating in N 67.55 E 23.48 h=500 a.s.l. in Finland. In winter icing is severe and an ice prevention system in wind turbine blades is compulsory. The Olos wind farm consists of five Bonus Mk IV 600 kW wind turbines. All turbines are equipped with an ice prevention system called JE-System.

A separate measurement 40 m high mast locates 115 m from the nearest wind turbines. In addition to normal meteorological measurements, blade heating power and icing are measured. Ice free measurement instruments are in use. Video monitoring for ice detector has been installed during the spring 2002.

Pori, Finland

The wind farm consists of 8 wind turbines of 1 MW nominal power supplied by the Danish manufacturer Bonus Energy A/S. The wind farm was installed in 1999 in Pori, western coast of Finland (N 61.3°, E 21.2°).

For wind and icing measurements an 85 m high mast was erected at the Pori wind farm in the autumn of 1999 during the follow-up project. A high mast is needed to reach the highest tip position of the Bonus 1 MW wind turbine. Also effective power from turbine 1, blade heating power and icing information from the turbines are recorded.

Luosto, Finland

The FMI test station is located in northern Finland. Site locates 515 m a.s.l. Measurement platform is instrumented extensively including several ice-free anemometers, temperature and humidity sensors, and solar radiation measurement equipment (Fig. 4). Also measurements of icing are done using Labko and Roremount ice detectors, Vaisala present weather sensor and two video monitoring systems.

Fig. 4: EUMETNET wind sensor test at Luosto fell in Finland. Different sonic and cup anemometers under icing conditions [4].

Oberzeiring, Austria

Partially demonstration wind farm will be erected during the summer 2002. Farm consists of 12 Vestas 1.3 MW wind turbines. The site is located at 1835 m a.s.l. Severe weather conditions prevail during winter months. Meteorological mast for wind and icing measurements will be erected on the site. (Fig 1)

Plankogel, Styria-Austria

Site consists of one 750 kW NEG Micon wind turbine and measurement mast and is located at 1450 m a.s.l. Measurements of wind speed and direction, humidity, temperature, pressure, radiation, visibility and icing will be made near the wind turbine. During winter months intensive measurements of icing on the wind turbine will be made.

Suorva, Sweden

Site consists of one 600 kW Bonus wind turbine and meteorological mast. Site is surrounded by mountains and therefore does not fulfil the recommendations of IEC standards.

The data will be used for verification of operation and failures of different types of turbines and different design of components. To get more operational data questionnaires will be sent especially to power plants operated under icing conditions in mountains in Spain, Italy, UK, Switzerland and many Eastern European Countries.

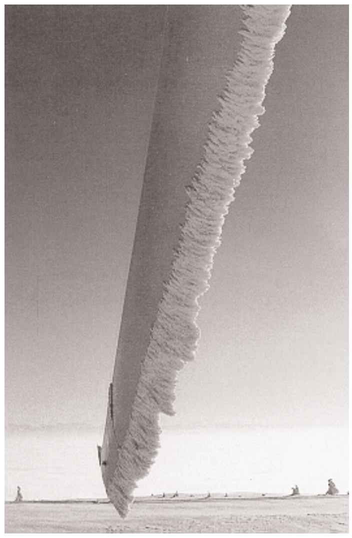

Fig. 5: Iced wind turbine blades in Germany.

Production and failure statistics

The production and failure statistics of wind turbines in Germany and Finland are used in the project to get an overview of the effect of icing on the wind turbines. These databases enable the comparison between meteorological observations and data with the practical experience from operators of wind turbines. This is made to explain the discrepancy and difference of reported experience and consequences of icing between observations from close-by wind turbines.

3. Experience and Data from Other Projects

3.1 WECO-project

Many aspects of the NEW ICETOOLS-project were dealt with in the EU-sponsored WECO-project.

Ice throw from blades may be a safety problem especially when turbines are close to roads, buildings or other human activities. In the WECO project the distances of ice pieces thrown by a rotating turbine were estimated based on theoretical calculations and field observations [2]

The present icing map for Europe was produced within the WECO project using meteorological data from over 100 observation stations. The new icing map under NEW ICETOOLS will include more stations, new methodology and latest experience achieved e.g. in the EUMETNET SWS project.

Icing of blades typically strongly reduces the power production of turbines. Up to now quite few monitored data on power reduction versus the amount and the shape of ice exist. However, according to examples of ice observed upon blades a calculation method to predict power losses due to icing was produced in the WECO project [2]. In the NEW ICETOOLS project it is hoped to get experimental data on this issue to verify and improve the modelling of power losses for different types of large wind turbines.

3.2 EUMETNET SWS-II-project

Wind sensors are required for wind energy assessment, verification of models [6], power curve analyses and operation of wind turbines. Even slight icing of anemometers will strongly reduce the measured wind speed [3]. Icing of wind sensors is much more frequent and usual in Europe than generally expected.

Unfortunately quite a few ice-free sensors are available today. And unfortunately very few of the ice-free sensors available are accurate and reliable enough to be used for proper wind energy business. However, a couple of ice-free and non-ice-free wind sensors may be used during operation to control icing of wind turbines.

Fig. 6: EUMETNET wind sensor test at Mont Aigoual in France. Degréane DEOLIA96 sensors are currently used in the Météo-France network. This model has shaft heating. Cups on the left and the vane on the right [4].

Concerning wind power business there is a need to specify ice-free anemometers to be used for different purposes mentioned above. Therefore results from ongoing projects like EUMETNET SWS II [4] are required.

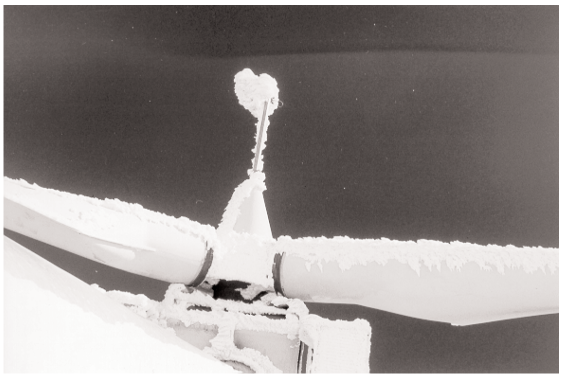

Fig. 7: Iced blades and control anemometer in Switzerland.

3.3 IEA Collaboration

At present quite little information on statistics on operation of wind turbines under icing conditions is available. New optional operators of turbines at possible icing sites also would like to have some information of experience achieved from existing sites like e.g. that from Sweden [7].

This kind of data is collected and produced also under the framework of IEA R&D Wind in the Annex XIX Wind energy in cold climates. The annex is a cooperation between Finland, Sweden Denmark, Norway, Switzerland, Canada and USA [7].

3.4 Standardization and Certification

Certifying wind turbines for cold and mountainous regions require reliable procedures for the prediction of ice amount during standstill and operation. International design standards take icing load cases into consideration in different ways. The IEC-61400-1 ed2 Wind Turbine Generator Systems - Part 1 Safety Requirements recommends to take ice loads into account but a special load case is not given. However, investigations concerning icing of wind turbines during operation at different places in Europe showed that heavy ice loads are not negligible. Thus, based on these experiences a proposal for simplified load assumptions for design codes has been worked out in [1]. However, the distribution forming the highest ice mass is the linear distribution. A method taking this distribution into account for load calculations is described below. The maximum depth of ice amount at the tip is thereby dependent on the blade's chord length. Measurements and observations for different sized wind turbines are known and were used as a basis for the approximations [2].

4 Dissemination of Information

Information on the NEW ICETOOLS project will be found e.g. on www-pages www.fmi.fi. It is also most likely that BOREAS VI "conference", the traditional meeting to discuss icing problems since 1992, will take place in Finnish Lapland (www.pyha.fi) at early April 2003.

5. Summary

Icing of structures like wind turbines, wind sensors, power lines etc. is much more common in Europe than typically expected e.g. by wind power people. Icing is not only a problem for the far north, but also for inland/mountainous sites in Germany, UK, Spain, Italy, Austria, and also in most of the new EU candidate states.

In this paper the new project, which will study the operation of wind turbines under icing conditions and make verification on various models on ice/rime accretion upon blades, on loads due to icing etc. compared to effects observed on wind turbines has been shortly described. The project focuses on production of a new icing map for Europe. The duration of the project is 1 Jan 2002 - 31 Dec 2004.

The project highly appreciates your co-operation concerning our questionnaire sent out later this year to collect data on operation of wind turbines under icing conditions.

Also any other information concerning icing events and operation of wind turbines under icing conditions is welcome. Please send your information to:
FMI Energy, Finnish Meteorological Institute, Vuorikatu 24, 00100 Helsinki, Finland.

6. Acknowledgements

The project NEW ICETOOLS is partially supported by the EU Commission under the Contract Nr. NNE5/2001/259.

7. References

[1] Seifert, H. and Tammelin, B., 1996. Icing of wind turbines. Final report: JOU2-CT93-0366. DEWI.

[2] Tammelin, B., Cavaliere, M., Holttinen, H., Morgan, C., Seifert, H. and Säntti. K., 2000. Wind energy production in cold climate. Meteorological publications No 41. Finnish Meteorological Institute. pp. 41.

[3] Kimura, S., Tammelin, B., Peltomaa, A. and Tsuboi, K., 2000. Icing effect on a cup anemometer. Meteorological publications No 44. Finnish Meteorological Institute. pp. 41.

[4] Tammelin, B., Heimo, A., Leroy, M., Rast, J. and Säntti, K., 2001. Meteorological measurements under icing conditions - EUMETNET SWS II project. Reports 2001:6 . Finnish Meteorological Institute. pp. 52.

[5] Tammelin, B., Bergström, H., Botta, G., Douvikas, D., Rathman, O., Strack, M. and Hyvönen, R., 2001. Verification of wind energy prediction produced by Wasp and some mesoscale models in European mountains. In proceedings of European Wind Energy Conference 2001.

[6] Schönborg, A. and Blomgren, L., 2001. Two year´s experience of three different turbines on the same site - Rodovålen- in the very middle of Sweden. In the proceedings of BOREAS V conference. CD-rom. Finnish Meteorological Institute.

[7] H. Holttinen, G. Ronsten, L. Tallhaug, P. Lundsager, R. Horbaty, I. Baring-Gould, A. Lacroix, E. Peltola, T. Laakso, The State-of-the-art of wind turbines in icing and cold climates, presented at 2002 Global Wind Power Conference, 2-5 April 2002, Paris, France.

[8] Tammelin, B. and Säntti, K., (Ed.), 2001. Wind power production in cold climate - BOREAS V. Finnish Meteorological Institute.