1. BACKGROUND

Wind energy is increasingly used in arctic and cold climates and adapted technology has been developed. Various national activities are being conducted in a number of countries and the first steps from demonstrations into fully commercial implementations have been taken. International co-operation has been carried out e.g. within the European Union's non-nuclear energy programme and the topic has specifically been addressed at e.g. the biannual Boreas-conferences in Finland and at the Arctic Wind Energy Conference at Risø in 1993.

Wind turbine operation is also affected by cold temperatures and formation of ice on the blades and the supporting structures. Cold temperatures can be handled by material selections known in other technical fields but to prevent icing, new techniques have to be – and have been – developed. Icing affects the reliability of anemometers, which are commonly used in turbine control and resource estimation, changes the aerodynamics of the blades, which might eventually stop the turbine. In addition, ice accretion can lead to an increase in structural loads and cold temperatures might change the dynamics of the blades, although, the latter is still to be verified. Ice appears in different forms under different atmospheric conditions, namely frost, clear, ice or glaze, freezing rain, wet snow or rime ice. The rate of accretion is heavily dependent upon both location and height. Formation of ice might also pose a risk to public safety even in areas where icing occurs merely occasionally.

Applied technology has been developed along some different paths and various solutions are being tested. With regard to blade heating, different systems are being marketed, i.e. electrical, hot air and microwave heating. Other technologies adapted for cold/icing conditions relate to anemometers, material selections and other monitoring equipment.

Technical development is continuing and several solutions are being demonstrated. As the applications are entering a commercial phase, there is a need to gather experiences in a form that can be utilised by developers, manufacturers, consultants and other financiers.

2. OBJECTIVES

The objectives are to:

(a) Gather and share information of wind turbines operating in cold climates;

(b) Establish a site-classification formula, combining meteorological conditions and local needs. This is of relevance for wind turbine designers, manufacturers, project developers and wind energy producers;

(c) Establish a classification formula on standard and adapted technologies and operational strategies to match the site assessment classification. It has relevance for the same group described in sub-paragraph (b), in particular project developers, decision makers and their advisors/consultants;

(d) Monitor the reliability and availability of standard and adapted wind turbine technology that has been applied;

(e) Establish and present guidelines for applying wind energy in cold climates.

3. MEANS

The activities will focus on fundamental questions related to cold climate applications of wind energy, i.e. meteorological and operational information. Adapted technical development is continuing in different countries and is reaching a competitive stage. The actual technical and operational developments will be included to the extent necessary for meeting the objectives.

a) Site Assessment and Classification

When planning for wind turbines to be sited in cold climate conditions the specific properties of the site must be considered. To some extent, these properties can easily be taken into account but in some cases special means are necessary.

A site assessment under cold climate conditions is difficult to carry out, as the functionality of instruments is difficult to verify. Both wind and the icing conditions need to be analyzed in order to enable the making of proper production estimates and a selection of the most suited technology. The work will therefore include:

(1) Methods for monitoring icing in site assessment;

(2) Methods for assessing wind conditions in cold climate regions.

The basis for this work is the development of a classification procedure taking the following properties into account:

(1) Energy demand;

(2) Grid infrastructure;

(3) Wind conditions and measurements;

(4) General climate conditions;

(5) Temperature levels; extremes and variations

(6) Type and rate of icing;

(7) Site accessibility;

(8) Safety aspects;

(9) Other demands related to infrastructure;

(10) Offshore locations.

The classification procedure should take into account all aspects of a cold climate and should recommend data sources or ways to obtain new data. It should, as far as possible, be based upon existing information and recommend data sources or ways to obtain new data. The activity will support entering new wind energy markets and can be extended to cover also non-OECD countries.

b) Technology and Operations Classification

When evaluating bids or proposed specifications by bidders relating to classified sites as described in sub-paragraph a) above, the proposed technical and operational solutions should be classified and processed accordingly.

This approach should include the classification of technical features such as:

(1) Material specifications;

(2) Temperature control;

(3) Lubricants;

(4) Ice detection, etc.

and operational strategies such as:

(1) Operation only within specified temperature ranges;

(2) Turbine shut-down if icing occur, etc.

Methods for predicting ice accretion and methods to prevent it from affecting wind turbine operation will also be assessed. However, the cost of attaining a gain in energy production is hard to predict due to a lack of knowledge concerning the benefit of ice prevention as well as the best choice of technology.

The activity will make it possible to correlate manufacturers' proposed solutions with the classification of the site specifications and thus facilitate a systematic and efficient assessment of bids and other proposals. The activity will thus support wind energy developers who whish to start activities in new markets areas.

c) Operation and Performance Experiences

Wind turbines are being operated under various icing conditions both with and without adapted technology. Various national production and failure statistics sometimes also contain information on e.g. icing but on a global level there is no general knowledge of how much production is lost due to extraordinary climatic effects. The project would thus contain:

(1) Monitoring of production and failure events, related to operation and maintenance under cold conditions;

(2) Development of power performance measurement techniques under cold climate conditions;

(3) Development of methods to monitor icing events during operation;

(4) Monitoring availability and reliability of standard as well as adapted technology during extreme events;

(5) Gathering information and experiences from construction under cold climate conditions;

(6) Assessment of the reliability of anemometers, ice detectors and other instruments.

The monitoring should be carried out following a standard procedure in order to enable comparison of results on a scientific level. At the same time, experiences from applying standard cold climate technology and materials in wind turbines should be gathered and assessed. The procedures will be established at the beginning of the project.

d) Extraordinary Operational Events

In addition to the overall monitoring, specific sites representing different conditions will be chosen for detailed monitoring of extraordinary events, e.g. icing, storms, voltage losses, etc. The number of sites should be large to give a representative spread of conditions but manageable.

Proven technical methods should be used for monitoring, in order to have comparable results. Different methodologies might, however, be used under different conditions. The procedures for monitoring and dissemination of information will be agreed upon at the beginning of the project.

Finland

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Paljasselkä	NORDTANK	1	0.065	Active	400	heavy	-30C	Yes	Yes
Korsnäs	NORDTANK	4	0.8	Active	0	slight	-30C	No	Yes
Pyhätunturi	WINDWORLD	1	0.22	Dismantled	510	heavy	-30C	Yes	Yes
Sottunga	VESTAS	1	0.225	Active	0	slight	-30C	No	Yes
Siikajoki	NORDTANK	2	0.6	Active	0	slight	-30C	No	Yes
Kalajoki	NORDTANK	2	0.6	Active	0	slight	-30C	No	Yes
Kemi	NORDTANK	3	0.9	Active	0	slight	-30C	No	Yes
Pori	NORDTANK	1	0.3	Active	0	slight	-30C	No	Yes
Hailuoto	NORDTANK	2	0.6	Active	0	slight	-30C	No	Yes
Lammasoaivi	BONUS	3	1.5	Active	710	heavy	-30C	Yes	Yes
Hailuoto	NORDTANK	2	1	Active	0	slight	-30C	No	Yes
Ii	NORDTANK	1	0.5	Active	0	slight	-30C	No	Yes
Eckerö	VESTAS	1	0.5	Active	0	slight	-30C	No	Yes
Kökar	ENERCON	1	0.5	Active	0	slight	-30C	Yes	Yes
Vårdö	ENERCON	1	0.5	Active	0	slight	-30C	Yes	Yes
Finström	ENERCON	2	1.6	Active	0	slight	-30C	Yes	Yes
Siikajoki	NORDTANK	2	1.2	Active	0	slight	-30C	No	Yes
Lemland	VESTAS	4	2.4	Active	0	slight	-30C	No	Yes
Olos	BONUS	5	3	Active	520	heavy	-30C	Yes	Yes
Föglö	ENERCON	1	0.6	Active	0	slight	-30C	No	Yes
Lumijoki	VESTAS	1	0.66	Active	0	slight	-30C	No	Yes
Kuivaniemi	NEGMICON	6	5	Active	0	slight	-30C	No	Yes
Meri-Pori	BONUS	8	8	Active	0	slight	-30C	Yes	Yes
Kotka	BONUS	2	2	Active	0	slight	-30C	No	Yes
Oulu	WINWIND	1	1	Active	0	slight	-30C	No	Yes
Oulunsalo	NORDEX	1	1.3	Active	0	slight	-30C	Yes	Yes

Sweden

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Suorva	BONUS	1	0.6	Active		slight		Yes	
Rodovålen	BONUS	1	0.6	Active		heavy		Yes	
Rodovålen	NORDEX	1	0.6	Active		heavy		Yes	
Rodovålen	NEGMICON	1	0.6	Active		heavy		No	
Kall	VESTAS	1	1.7	Active		heavy		Yes	
Kvarkenvind, Umeå	BONUS	1	0.6	Active		slight		No	
Äppelbo	NEGMICON	1	0.9	Active				No	
Klimpfjäll	NEGMICON	3	2.7	Active				No	
Kiruna	NEGMICON	6	5.4	Active				No	

Switzerland

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Grenchenberg	BONUS	1	0.15	Active	1300	slight	-20C	no	no
Simplon pass	Husumer Schiffswerft	1	0.03	Active	2000	heavy	-20C	no	no
Gäbris	LAGERWEY	1	0.08	Active	1100	slight	-15C	no	no
Mt Crosin	VESTAS	6	4.16	Active	1200	slight	-20C	no	no
Titlis	Husumer Schiffswerft	1	0.03	Active	3000	heavy	-25C	no	no
Guetsch, Andermatt	LAGERWEY	1	0.75	Active	2300	heavy	-25C	yes	yes
StMoritz				Project	2200	heavy	-25C		
Crêt Meuron				Project	1300	slight	-20C		
Gotthard				Project	2100	heavy	-25C		
Grimsel				Project	2150	heavy	-25C		

Austria

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Tauernwindpark,	Vestas			Under Constr.					

United Kingdom

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Windy Standard	NEGMICON	36	21.6	Active	600	slight			
Hagshaw Hill, 50 km South	BONUS	26	15.6	Active		slight			

Italy

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Aqcua Spruzza		1	0.3	Active		heavy			

Canada

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
North Cape (Prince	Vestas	8	5.28	Active		slight	-25 C	no	yes
Metane (Québec)	NEG-Micon	3	2.25	Active		slight	-30 C	no	yes

Le Nordais, phase 1	NEG-Micon	76	57	Active		slight	-30 C	no	yes
Le Nordais, phase 2	NEG-Micon	57	42.75	Active		slight	-30 C	no	yes
Tiverton (Ontario)	Tacke	1	0.6	Active		slight	-30 C	no	yes
Pickering (Ontario)	Vestas	1	1.8	Active		slight	-25 C	no	yes
Gull Lake (Saskatchewan)	Vestas	1	3.96	Active		almost none	-30C	no	yes
Pincher Creek (Alberta)	Danish Windmatic	3	0.195	Active		almost none	-30 C	no	yes
Pincher Creek (Alberta)	Danish design	1	0.15	Active		almost none	-30 C	no	yes
Cowley (Alberta)	US Windpower (Kenetech) , Nordex	72	40.095	Active		almost none	-30 C	no	yes
Pincher Creek , Castle	Vestas	60	39.54	Active		almost none	-30 C	no	yes
Hill Spring (Alberta)	Vestas	4	2.46	Active		almost none	-30 C	no	yes
Peigan Nation Reserve	NEG-Micon	1	0.9	Active		almost none	-30 C	no	yes
Heackel Hill, White Horse	Bonus, Vestas	2	0.81	Active		heavy	-40 C	yes	yes

China

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Urumqi, Xinjiang	BONUS	13	1.95	Active			-40 C	no	yes
XWPGP, Xinjiang Province	BONUS	4	1.2						
XWPGP, Xinjiang Province	BONUS	4	2						
XWEC, Xinjiang Province, (AN)	ANBONUS	10	1.2						
Buerjin Hydro Power, Xinjiang Province (AN)	ANBONUS	3	1.35						
IMEPA, Inner Mongolia	BONUS	12	7.2						

Russia

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Murmansk	NEG-Micon	1	0.2	Active		slight		no	

Japan

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Tomamae Windfarm, Hokkaido	BONUS	20	20	Active	70				
Tomamae Town, Fuuraibo	BONUS	1	1	Active					
Hamatonbetsu, Hokkaido	BONUS	3	3	Active					
Enbetsu, Hokkaido	BONUS	3	3	Active					
Hamatonbetsu Green Fund, Hokkaido	BONUS	1	1	Active					
Iwaya Wind Farm, Tohoku district, Honshu	BONUS	25	32.5	Active					

USA

Site	Turbine Manufacturer	Number of turbines	Total MW	Status	Site Elevation m.a.s.l	Site Icing	Site Low Temp	Modifications Icing	Modifications Low Temp
Lake Benton,Minnesota			200	Active					
Searsburg,Vermont			6	Active		slight			