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Database on wind characteristics. Contents of database bank

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Database on Wind Characteristics

Contents of Database Bank

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Abstract The main objective of IEA R&D Wind Annex XVII - Database on Wind Characteristics - is to provide wind energy planners and designers, as well as the international wind engineering community in general, with easy access to quality controlled measured wind field time series observed in a wide range of environments. The project partners are Sweden, Norway, U.S.A., The Netherlands, Japan and Denmark, with Denmark as the Operating Agent.

The reporting of IEA R&D Annex XVII falls in three separate parts. Part one deals with the overall structure and philosophy behind the database, part two accounts in details for the available data in the established database bank and part three is the Users Manual describing the various ways to access and analyse the data.

The present report constitutes the second part of the Annex XVII reporting. Basically, the database bank contains three categories of data, i.e. *i*) high sampled wind field time series; *ii*) high sampled wind turbine structural response time series; and *iii*) wind resource data. The main emphasis, however, is on category *i*). The available data, within each of the three categories, are described in details. The description embraces site characteristics, terrain type, measurement setup and the amount of available data.

IEA R&D Wind Annex XVII
Database on Wind Characteristics

http://www.winddata.com/

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Contents

1. Background

In 1996, the EU-DG XII (JOULE) project “Database on Wind Characteristics” was started. The project was concluded at the end of 1998 and resulted in a unique database of quality controlled and well-documented wind field measurements in a standardised format. The established data bank was supplemented with tools to enable access and simple analysis through an Internet connection using the World-Wide-Web. The contents and the facilities are reported in [1].

As a follow-up to the JOULE project, Annex XVII, within the auspices of the IEA R&D Wind, has been formulated with Sweden, Norway, U.S.A., The Netherlands, Japan and Denmark as active participants. The Annex entered into force on 1st January 1999, and will remain into force for an initial period of two and a half year.

The main objective of Annex XVII is to provide wind energy planners and designers, as well as the international wind engineering community in general, with easy access to quality controlled measured wind field time series observed in a wide range of environments. From its inception Annex XVII has successfully met the purpose by ensuring that the database is always on-line and available through the Internet, and by making possible and managing the continuous development and dissemination of the database.

2. Introduction

The reporting of Annex XVII falls in three separate parts. Part one deals with the overall structure and philosophy behind the database (including the applied data quality control procedures), part two accounts in details for the available data in the established database bank and part three is the Users Manual describing the various ways to access and analyse the data.

The present report constitutes part two of the Annex XVII reporting. For each site, the description of the database bank embraces site characteristics, terrain type, experimental setup, measurement system and the amount of available data.

3. Available data - an overview

Basically, the database bank contains three types of data:

1) High sampled wind field time series;
2) High sampled wind turbine structural response time series;
3) Wind resource data.

The available data within each of these categories is described in details in the following sections. The description embraces site characteristics, terrain type, measurement setup and the amount of available data. As updating of “Database on Wind Characteristics” is an ongoing process, the present report is to be considered as snapshot of the data status. This version of the document reflects the data contents ultimo June 2001.

3.1 High frequency sampled wind field time series

The wind field time series are characterised by being represented by high frequency sampled raw values in the database. The sampling frequency is typically between 1 and 40 Hz depending on the particular site as well on the actual channel sensor.

Presently, the database includes wind field time series from 12 different countries inside Europe and 3 countries outside (Egypt, USA and Japan) distributed on 41 sites. In total more than 74000 hours of high sampled meteorological data are available. The present status is illustrated in Table 3-1, where the available data has been classified according to country, terrain type, type of orography and length of the data record. As seen, 7 different terrain types and 3 types of orography types are represented. For a definition terrain classes and classes of orography refer to [1].

Site	Country	Terrain	Orograhpy	Hours
Abisko	Sweden	ice	Mountain	230
Alsvik	Sweden	coastal	Flat	17500
andros	Greece	pastoral	Mountain	625
aspruzza	Italy	pastoral	Mountain	542
bockstig	Sweden	offshore	Flat	1239
cabauw	The Netherlands	pastoral	Flat	472
clape	France	scrub	Hill	242
ecn	The Netherlands	coastal	Flat	49
emden	Germany	coastal	Flat	781
hornsrev	Denmark	offshore	Flat	3164
Hurghada	Egypt	Sand	Flat	1385
jwe	Germany	rural	Flat	344
kwkoog	Germany	coastal	Flat	4
lamme	Denmark	pastoral	Flat	663
lavrio	Greece	pastoral	Mountain	759
lyse	Sweden	coastal	Mountain	3355
maglarp	Sweden	rural	Flat	41
midgrund	Denmark	offshore	flat	2075
Mttsukub	Japan	Forest	Mountain	2410
nasudden	Sweden	coastal	flat	2870
ntk1500	Denmark	coastal	flat	151
oakcreek	US	scrub	hill	3081
roedsand	Denmark	offshore	flat	619
sjorge	Portugal	coastal	Mountain	5
ski	Norway	coastal	hill	13174
skyv27	US	scrub	hill	164
skyv39	US	scrub	hill	138
sle	Norway	coastal	flat	3756
sprogoe	Denmark	coastal	flat	527
tarifa	Spain	pastoral	Mountain	280
tarifa_2	Spain	coastal	hill	663
tjare	Denmark	pastoral	flat	64
toboel_1	Denmark	pastoral	flat	2071
toboel_2	Denmark	pastoral	flat	1147
toplou	Greece	pastoral	mountain	172
tsukuba	Japan	rural	flat	1355
utlangan	Sweden	coastal	flat	27
vindeby	Denmark	offshore	flat	2063
vls	Norway	coastal	hill	5956
windy	Scotland	pastoral	mountain	405
zeeb	Belgium	coastal	flat	103
41 sites	*15 countries*			*74868*

Table 3-1: High sampled wind field time series ultimo June 2001.

3.2 Wind turbine structural response time series

For one site the high frequency sampled wind field time series are supplemented by high frequency sampled wind turbine structural response measurements. The structural recordings originate from measurements on a Vestas V39 (500 kW) wind turbine located in a wind farm in a rather complex terrain in Tehachapi, USA. The available time series reflects different modes of operation (start, stop, idling and operation) of the wind turbine.

The main characteristics of the available structural response data are presented in Table 3-2.

Site	Country	Terrain	Orograhpy	Hours
skyv39	US	scrub	Hill	138

Table 3-2: High frequency sampled wind turbine structural response time series.

3.3 Wind resource data

Wind resource data are statistical quantities (mean, max., min., standard deviation) typically based on a (high frequency) sampling records between 1 and 30 minutes. Due to the limited temporal resolution such data usually extend over very long time span, typically between 1 and 30 years. Presently, wind resource data are available from four different sites in Denmark, Sweden and Norway. The wind resource data include as a minimum both a wind speed signal and a wind direction signal for each site. The characteristics of the available wind resource measurements are summarised in Table 3-3.

Site	Country	Terrain	Orograhpy	Hours	Years
alsvik	Sweden	coastal	flat	17502	3
Cabauw	The Netherlands	Pastoral	Flat	123476	15
Risoe_m	Denmark	Pastoral	Flat	43848	5
ski	Norway	coastal	hill	6600	1
tjare	Denmark	pastoral	flat	33842	5
Vindeby2	Denmark	offshore	flat	48746	7
4 sites	*4 countries*			*274014*	*36*

Table 3-3: Wind resource data ultimo June 2001.

4. Available data - site presentation

All available sites were briefly categorised in the previous Chapter. The present Chapter contains a detailed description of these sites. The description accounts for detailed characteristics such as site classification, number and size of instrumented meteorological masts, number of wind speed and wind direction measuring channels, number of wind turbines in the close surroundings, sampling frequency and time extend of the data. Moreover, the measuring system is described and the original motivation for conducting the measuring campaign is set out. Furthermore a detailed site description including maps, photos and measured distributions is available on the web-server as a PDF document. An example of site description for the Swedish Bockstigen site is listed in Appendix A.

The presentation is structured according to the three classes of data. For the high frequency sampled wind field data, the above specified information are supplemented with plots of the turbulence intensity versus the mean wind speed. This type of plot provides a quick visual general view of the data material. For the high frequency sampled structural response data, the general information is supplemented by a plot showing the power production as function of the mean wind speed in order to illustrate the extend of stand still and normal operation modes of the turbine during the measuring campaign. The wind resource data information includes a plot of the probability density function of the observed mean wind speeds during one year, while all other distributions are available online.

4.1 High frequency sampled wind field time series

Site = Abisko, Lapland, Sweden

Site code **Abisko**

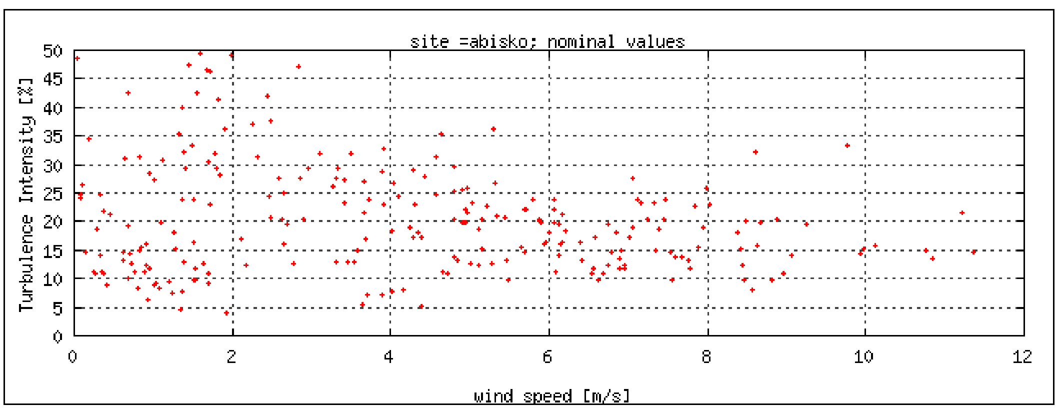
Dominating terrain/ orography	Ice	Mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	2 (3)	2 (3)
Number of sonics / height of met. Mast.	0	22 m
Hours of measurements / frequencies	230	

Project motivation
Measurements from a frozen lake in a mountainous area - in Lapland.

Measurement system
The instrumentation consists only of 3-component hotwires.

Comments
All measurements are recorded with hotwires.

Acknowledgements: Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Alsvik, Gotland, Sweden

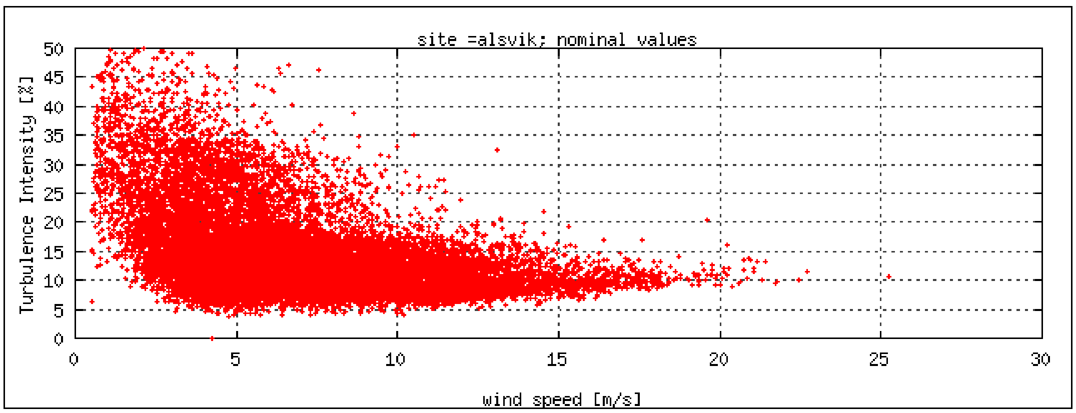
Site code **Alsvik**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	2	4
Number of channels with wind speed / wind direction	16	16
Number of sonics / height of met. Mast.	0	56 m
Hours of measurements / frequencies	17500	Appr. 1 Hz

Project motivation
Meteorological measurements from flat, coastal site on Gotland equipped with four wind turbines.

Measurement system
1 Hz data at eight levels on two 54 m towers during four years. 20 Hz data at three levels on one 54 m tower during one year.

Acknowledgements: Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Andros, Greece

Site code **Andros**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	625	1 Hz

Project motivation
The main objectives of the project were to a) develop draft design guidelines for wind turbines in simple terrain wind farms, b)investigate the behaviour of wind turbines in undulating and complex terrain wind farms and c)extend simple terrain design guidelines to complex terrain

Measurement system
Full scale measurements at a wind farm sited in mountainous terrain consisting of seven V27-225kW fixed speed, variable pitch wind turbines. Measurements of wind speed and direction were carried out at three heights a.g.l. on two meteorological masts using six cup anemometers and six vanes, in order to define the operational characteristics of one of the seven wind turbines in relation to the wind regime of the site.

Acknowledgements
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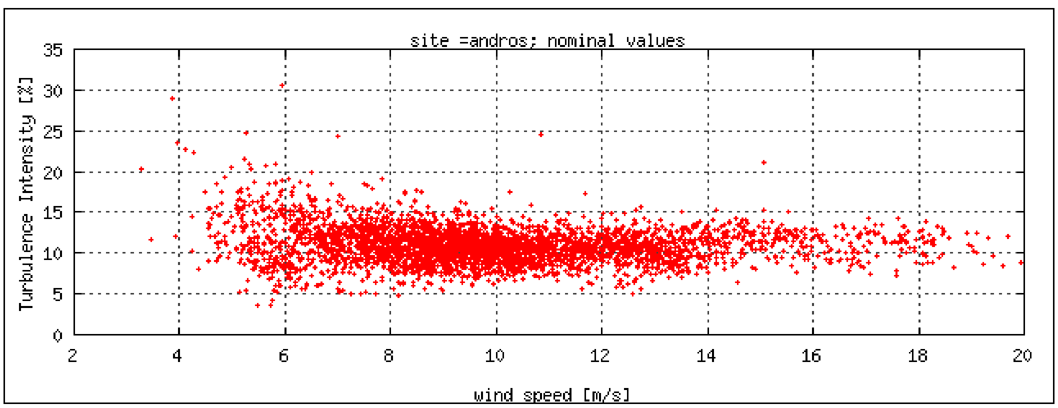

Nominal turbulence vs. wind speed.

Site = Aqua Spruzza, Italy

Site code **Aspruzza**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	1	8
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	542	1 Hz

Project motivation

The Acqua Spruzza wind turbine test site has been built by ENEL S.p.A. within the framework of a programme aimed at evaluating the technology of commercial medium-sized machines operating in complex terrain and very hostile climate and with special regard to availability, energy output, lifetime (through the monitoring of loads), operating and maintenance costs. The objective is to assess the viability and the economic attractiveness of wind farms in hostile terrain and to understand the risk, associated with the exploitation of these kind of sites. To this end, a suitable research programme has been outlined, comprising regular performance and load monitoring of the wind turbines and wind monitoring as well, through acquisition of both statistical and campaign series of data. The campaign wind data are available for the present Project “Database on Wind Characteristics”

Measurement system

A number of data acquisition systems are presently installed at the Acqua Spruzza test site, namely the Measurement Control and Monitoring system (MCM), the Scientific Measurement Systems (SMS) and the SQUIRREL data loggers. The MCM system allows the general monitoring of wind turbines and the wind measurements from conventional anemometers installed on two wind masts, namely M1 and M2, through the recording of 10-min main statistics. The SMSs are specifically dedicated to the performance and load monitoring of three wind turbines, through the acquisition of extensive campaign data (20 - 60 Hz). The SQUIRREL data loggers are dedicated to summary wind data acquisition, some of which from sensors specially designed for operation in cold climate, and to the collection of wind data time series at 1 Hz frequency from mast M1. The wind campaigns recorded by a SQUIRREL data logger are available for the present Project.

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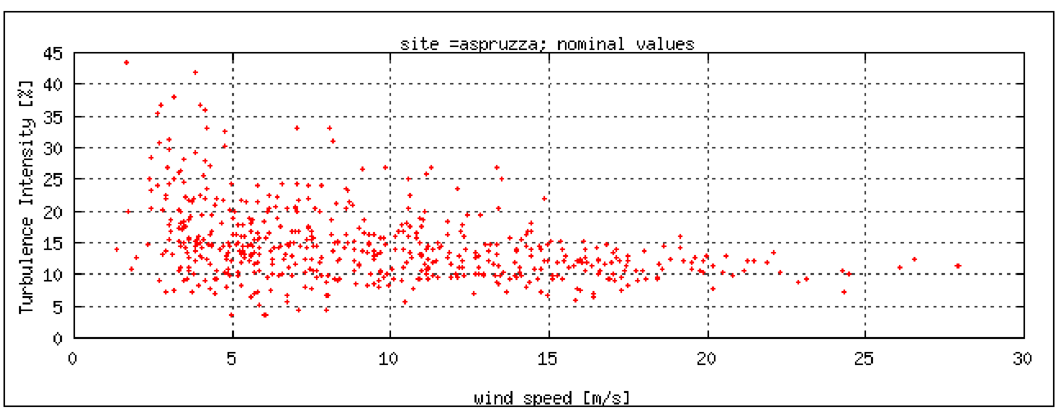
Massimo Cavaliere, ENEL Research, Renewable unit, Italy.



Nominal turbulence vs. wind speed.

Site = Bockstigen, Gotland, Sweden

Site code **Bockstig**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	1	5
Number of channels with wind speed / wind direction	4	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	1239	

Project motivation

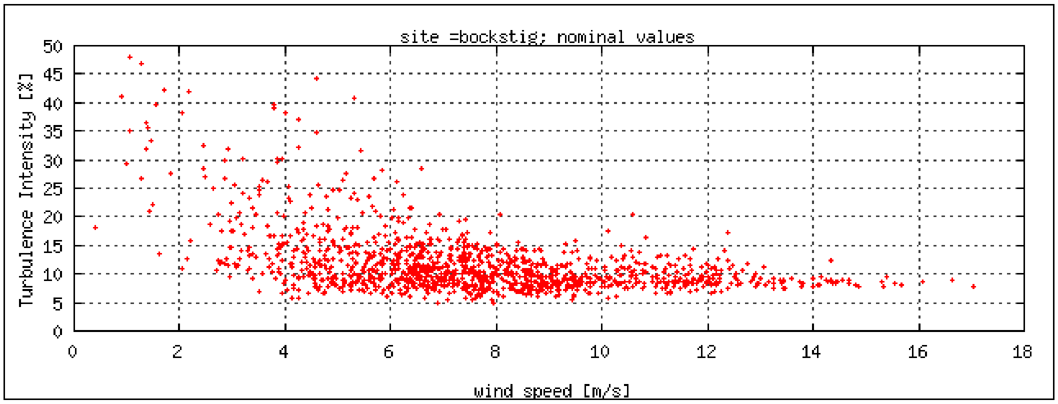
The Bockstigen off-shore wind farm consists of five 500 kW wind turbines erected three km of the SW coast of the island of Gotland on the Baltic. The project was launched in order to gain experience from bottom mounted offshore wind turbine installation. Specifically, the method of drilling a hole for a monopile foundation, directly into the limestone rock, was in focus for the investigations.

Measurement system

Measurements are performed in one meteorological mast, and on one instrumented turbine (no measurements in the rotating system). Data are sampled by use of several loggers (DataScan 20 Hz), and the signals are transferred through an optical fibre cable (4500 m) to an onshore cabin. Data is continuously stored on video8 tapes.

Acknowledgements

Göran Ronsten, FOI (FFA), Sweden



Nominal turbulence vs. wind speed.

Site = Cabauw, The Netherlands

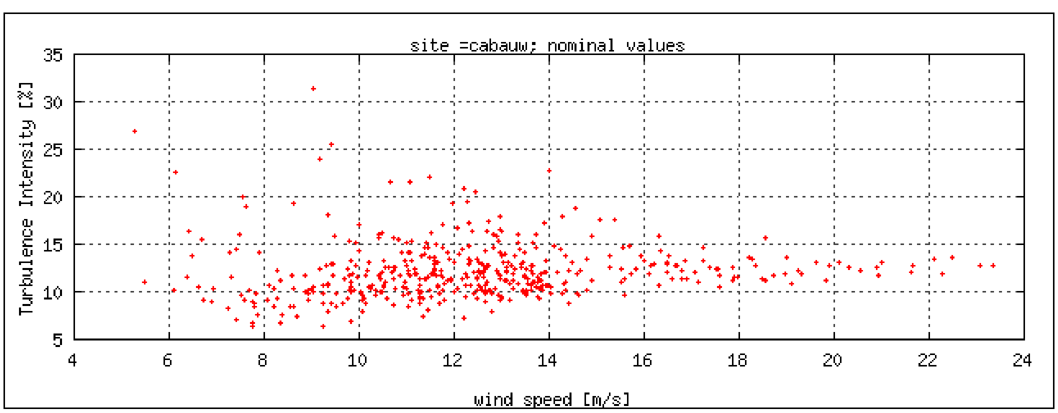
Site code **Cabauw**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	5	5
Number of sonics / height of met. Mast.	0	213 m
Hours of measurements / frequencies	472	

Project motivation
In the frame work of the project "a manual of design wind data for wind turbines ", measurements from the Royal Netherlands Meteorological Institute (KNMI) were used extensively. In this project a set of wind measurements of about 800 hr, measured in 1985 and 1986, was used. An important subject in this project was the frequency of occurrence of wind gusts and of wind direction changes. Wind data files in which average values (averaging time 600s) greater than 15 m/s are present at 20 m height, were classified as wind files with strong winds. The wind data in this subset (50 hrs) are made available for the "Database on Wind Characteristics". The KNMI allows the use of these data under the following conditions: Users of the data refer to the source of the data e.g. with the following sentence: The Cabauw wind data were made available by the Royal Netherlands Meteorological Institute (KNMI). The KNMI appreciates to be informed how the data were treated and likes to get relevant reports. In general commercial use of the data is not allowed. Information about the terms for commercial use can be obtained at the KNMI, attention to W.A.A. Monna, Section atmospheric research, P.O. Box 201, 3730 AE De Bilt, NL.

Measurement system
The Cabauw meteorological mast is a tubular tower with a height of 213 m and a diameter of 2 m. Guy wires are attached at four levels. From 20m upwards horizontal trussed measurement booms are installed at intervals of 20 m. At each level there are three booms, extending 10.4 m from the centreline of the tower. These booms point to the directions 10, 130, 250 degrees relative to North. The SW and N booms are used for wind velocity and wind direction measurements. These booms carry at the end two lateral extensions with a length of 1.5 m and a diameter of about 4 cm.

Acknowledgements
J.W.M.Dekker & Terry Hegberg, ECN, The Netherlands



Nominal turbulence vs. wind speed.

Site = La Clape, Narbonne, France

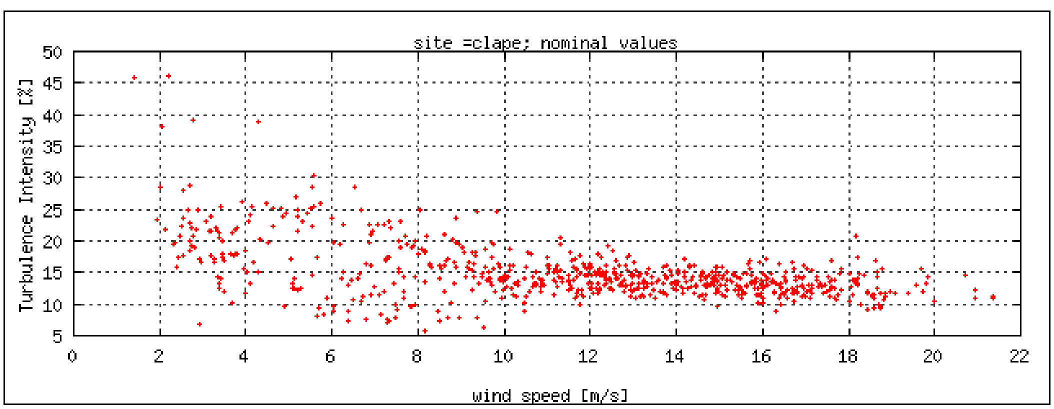
Site code **Clape**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	2	2
Number of sonics / height of met. Mast.	1	41 m
Hours of measurements / frequencies	242	2 & 8 Hz

Project motivation
In the frame of the European Joule Program: concerning wind resource assessment over complex terrain, the purpose of this study is to provide a set of wind speed data for a hill in the South of France, a validation test for the software WASP and to improve the knowledge of turbulence over complex terrain.

Measurement system
On the summit, a 40 m high mast had been erected and equipped at three levels : at 10˜m a vane propeller, at 24 m a three directional gill propeller and at 40 m a sonic anemometer. At the reference point, the data acquisition system was a “micro-Mac” from Analog Device that allows a scan rate of 2 Hz. At the hill top, the data acquisition system was built around a portable Compaq 286 with a data acquisition workstation Keithley system 570 as interface, and two optical disk units Ricoh RO 5030E for data storage. Optical disks are 5’1/4 cartridge with a capacity of 2x293 MB each one.

Acknowledgements
Christian Sacre, CSTB, Nantes, France



Nominal turbulence vs. wind speed.

Site = Ecn, Petten, The Netherlands

Site code **Ecn**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	4	1
Number of channels with wind speed / wind direction	9	3
Number of sonics / height of met. Mast.	0	41, 41, 41 & 41m
Hours of measurements / frequencies	49	4 Hz

Project motivation

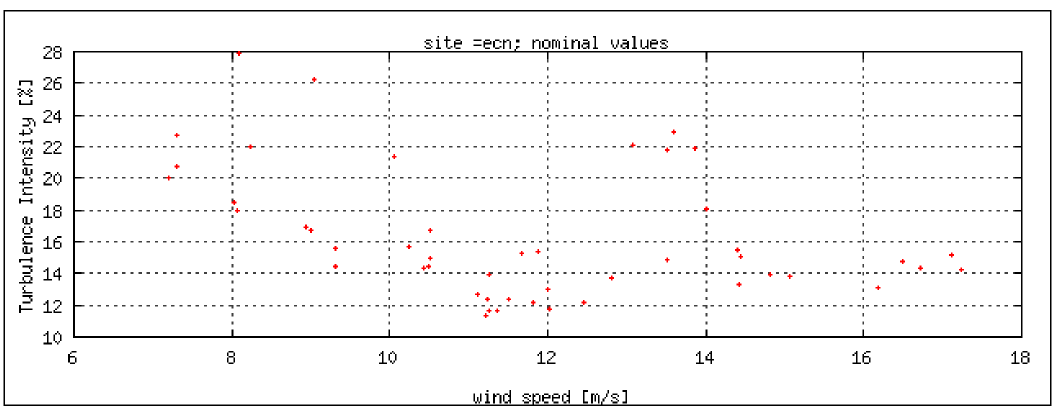
The primary goal was to design and build and test a flexible rotor (two blades, diameter 21.6 m) with passive tip-pitch control and a teetered hub with an elastomeric bearing. The FLEXTEETER rotor was tested at the 25m HAWT test facility of ECN. During the project the wind input was measured with a set of four meteorological masts. The wind data obtained as part of the test of FLEXTEETER are available for the "Database on Wind Characteristics".

Measurement system

The measurement system consists of 4 meteorological mast, mast no. 1, 2, 3 were placed West of the turbine and mast 4 at the East side. The measurements system was based on a PDP data logger and the data were transferred to a DIGITAL VAX system (VAX VMS operating system with data handling routines and programs developed at ECN). The data to be measured were divided in two groups: group 1, wind data with a recording frequency of 4 Hz; group 2, turbine operational data and mechanical load data with a recording frequency of 32 Hz. The maximum duration of a consecutive measurement with 32 channels in both groups was about 18 hrs.

Acknowledgements

J.W.M. Dekker, ECN, The Netherlands.



Nominal turbulence vs. wind speed.

Site = Emden, Germany

Site code **Emden**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	2	1
Number of sonics / height of met. Mast.	0	68 m
Hours of measurements / frequencies	781	20 Hz

Project motivation

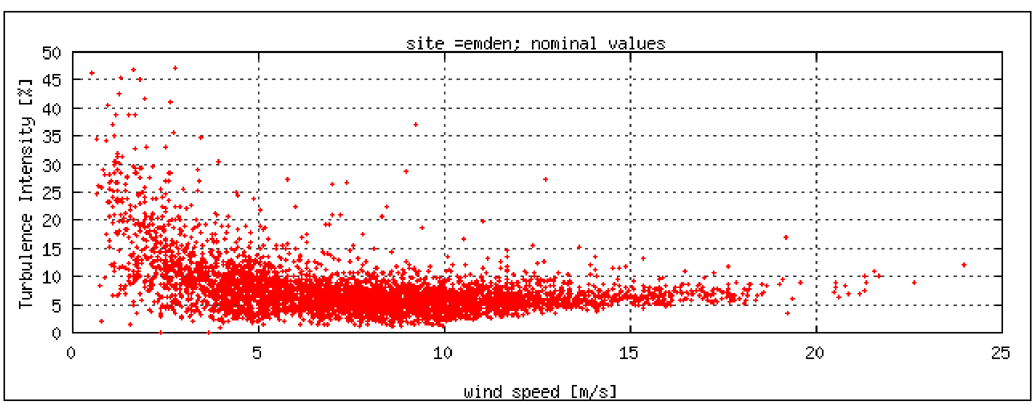
Due to the increase in size of today's series production wind turbines into the MW-range optimised tower designs and minimised use of material are necessary for augmentation of these turbines' economics. Exact knowledge of the loads is of vital importance in the design and certification process. To arrive at a dependable prediction of fatigue loads they are either calculated using elaborate computer simulations of the turbine's dynamic behaviour or estimated by means of simplified fatigue load spectra. Lately, the use of load measurements becomes more and more important in that issue. In Germany both, calculation and estimation are used. Recent measurements have given rise to a discussion about the adequacy of the use of simplified load assumptions. As a contribution to settle this discussion "real life"-measurements are carried out by DEWI within a research project which is co-ordinated by VDMA (the German machinery and plant manufacturers' association) and partly funded by the German Research Ministry (BMBF) and AVIF (Research society of the working alliance between the iron, steel and metal working industries).

Measurement system

A 68 m high mast served as bases for the meteorological measurements. The meteorological data were collected by two independent data loggers. An Ammonit data logger was used for the long term recording of 5 minute averages of all data relevant for the power curve evaluation of a 1.5 MW WEC. In Addition a modular processor-controlled data acquisition system (MOPS) served for investigations of the structural loads and dynamic behaviour of the turbine. Only the data gained from this system are relevant for the Database on Wind Characteristics. The sample rate was 20 Hz and time series with a duration of 600 seconds have been stored.

Acknowledgements

Christian Hinch, DEWI, Germany.



Nominal turbulence vs. wind speed.

Site = Horns Rev, Esbjerg, Denmark

Site code **Hornsrev**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of sonics / height of met. Mast.	1	50 m
Hours of measurements / frequencies	772	20 Hz

Project motivation

The purpose of the work are to investigate the wind and sea climates for the first of the two offshore wind farms in the Elsam area, i.e. the 150 MW Horns Rev wind farm to be built and commissioned by the end of year 2002. The Horns Rev site is located at a reef approx.14 km off Jutland in the North Sea in a very harsh environment. The water depths at the site vary between 6 and 12 m. In-depth knowledge of the environment at the offshore site was crucial to enable the evaluation of vital information, such as wind farm energy production prognoses, assessment of structural loads and the prediction of global long-term seabed changes and local scouring around the foundation**.**

Measurement system

A square lattice mast was erected on a mono pile close to the wind farm site at Horns Rev and mid May 1999 the meteorological measurement programme was initiated and later in June 1999 the marine measurement programme started. Cup anemometers are located at 15, 30, 45 and 62 m above sea level. Vanes are located 28, 43 and 60 above sea level. The 3-D sonic measurements are recorded at 40 m above sea level. Cup and vane signals are stored as 10 minute statistics while only 3-D sonic measurements are stored as time series.

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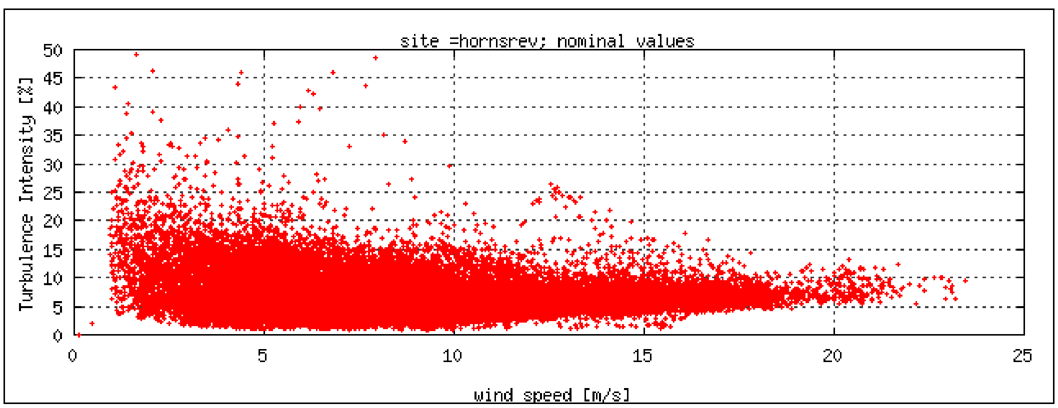
ELSAM & Søren Neckelmann, Tech-wise A/S, Denmark



Nominal turbulence vs. wind speed.

Site = Hurghada, Egypt

Site code **Hurghada**

Dominating terrain/ orography	Sand	Flat
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	4	2
Number of sonics / height of met. Mast.	0	
Hours of measurements / frequencies	1386	8 Hz

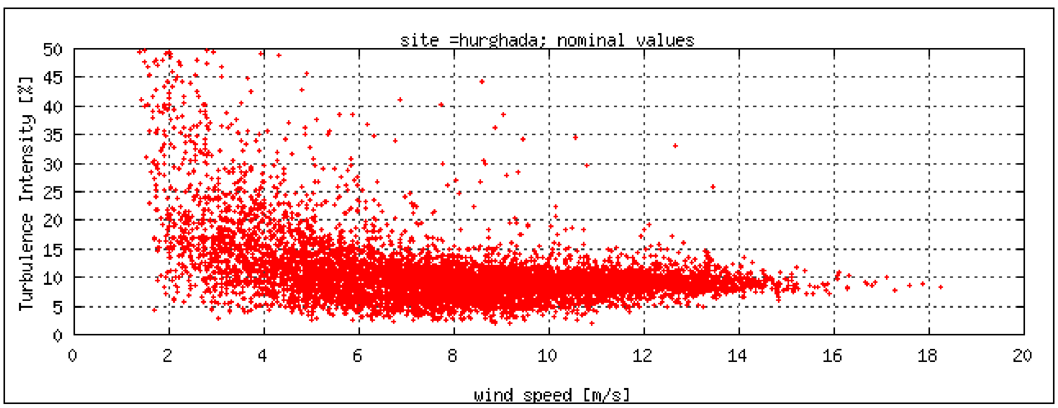
Project motivation
Characterising wind and turbulence for a desert location equipped with wind turbines during stable conditions. The measurements was ordered for a 2 month period.

Measurement system
Two standard meteorological masts with a height of 30 m, each equipped with 2 cups and one vane has been used. Signals has been recorded continiuosly with 8 Hz. The stability measurements are recorded on a third mast equipped with Anderaa meteorological instrumentation.

Instrumentation and measurement setup has been done in coorperation between Risø National Laboratories and Hurghada Wind Technology Center and the equipment used are identical to standard Risø measurement setup. Monitoring of the measurement program has been done by the staff at the Hurghada Wind Energy Technology Center.

Note: Each met. mast has its own measurement computer and it is been necessary to merge all the time series, and this caused some errors due to errors in the synchronisation.

Acknowledgements
Staff at the Hughhada Wind Energy Technology Center, Hurghada, Egypt.



Nominal turbulence vs. wind speed.

Site = Jade Wind Park, Wilhelmshafen, Germany

Site code **jwe**

Dominating terrain/ orography	Rural	Flat
Number of masts / wind turbines	1	4
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	0	130 m
Hours of measurements / frequencies	344	20 Hz

Project motivation

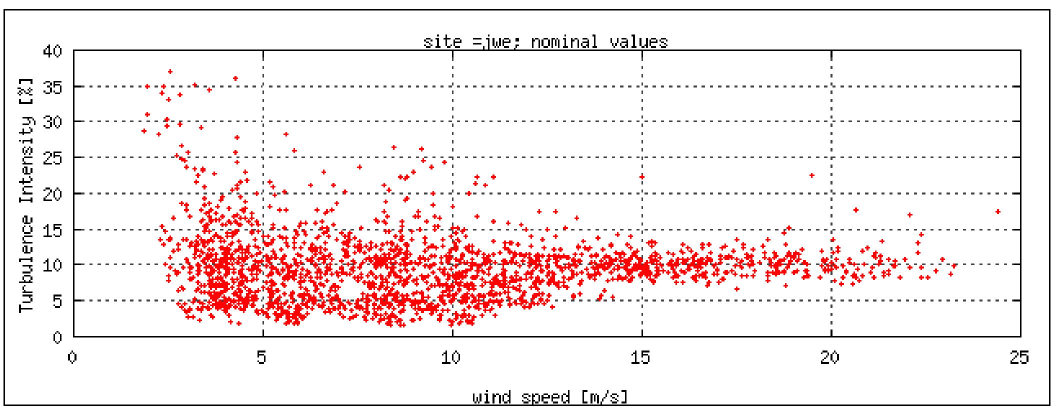
In the framework of the EU funded program “WEGA II Large Wind Turbine Scientific Evaluation Project” (Jou2-CT93-0349) a subproject CAN - Comparison of Aeolus II (located in Germany) and Naesudden II (located in Sweden) - was carried out to investigate the behaviour of two sister wind turbines with 3 MW rated power, but with different control mechanism and tower design. High resolution wind data recorded within this project at the Aeolus II to evaluate the mechanical loads also measured at the turbine are available for the “Database on Wind Characteristics”.

Measurement system

A 130 m high mast served as bases for the meteorological measurements. The meteorological data were collected by two independent data loggers. An Ammonit data logger was used for the long term recording of 5 minute averages of all data relevant for the power curve evaluation at the Aeolus II. In Addition a modular processor-controlled data acquisition system (MOPS) served for investigations of the structural loads and dynamic behaviour of the Aeolus II. Only the data gained from this system are relevant for the Database on Wind Characteristics. The sample rate was 20 Hz and time series with a duration of 600 seconds have been stored.

Acknowledgements

Christian Hinch, DEWI, Germany.



Nominal turbulence vs. wind speed.

Site = Kaiser Wilhelms Koog, Hamburg, Germany

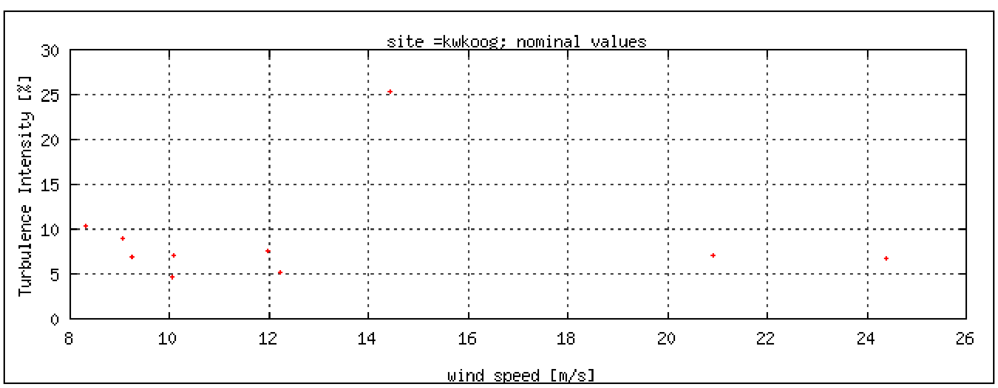
Site code **Kwkoog**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	3	1
Number of channels with wind speed / wind direction	20	18
Number of sonics / height of met. Mast.	0	150 m
Hours of measurements / frequencies	4	2 Hz

Project motivation
The main goal is to archive the wind data, which were measured during the test programme of the 3 MW wind turbine GROWIAN at Kaiser-Wilhelm-Koog at the North Sea coast of Germany from 1983 to 1987.

Measurement system
Two masts of 150 m height are placed 65 m east-south-east of the 3 MW wind turbine, their lateral distance is 52 m. 20 propellers and vanes are installed at pairs of booms of 12 m length to the right and to the left of the two masts so that an area of 75m x 100m is covered. The measuring frequency is 2.5 Hz and the duration of one measuring run is approximately 25 min. 300 runs are sampled between April 1984 and February 1987 at different inflow conditions. 10 data sets are available in this database, 9 for undisturbed inflow conditions at various wind speeds and stability conditions and one for flow from the wind turbine. The other data sets are available from the German Weather Service, Hamburg.

Acknowledgements
Horst Günther, Deutcher Wetterdienst Hamburg, Germany



Nominal turbulence vs. wind speed.

Site = Lammefjorden, Hornsherred, Denmark.

Site code **Lamme**

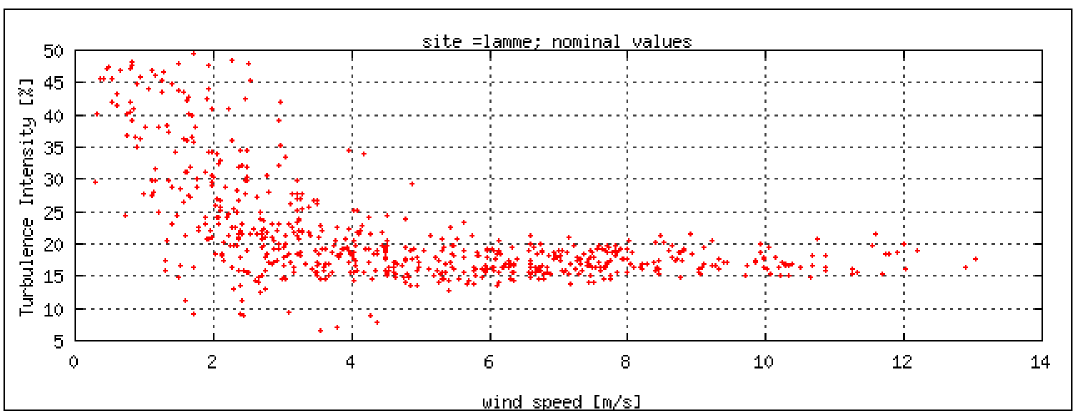
Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	4	0
Number of channels with wind speed / wind direction	10	9
Number of sonics / height of met. Mast.	1	10, 30, 30 & 45 m
Hours of measurements / frequencies	663	8 & 16 Hz

Project motivation
An attempt to gather data continuously for one year with sufficient spatial and temporal resolution for wind turbine design studies. Completed with around 90% availability with a longest uninterrupted series of 103 days. The Measuring Site: The current project built upon a previous field experiment conducted to collect data for lateral coherence research (Courtney 1987). For this purpose, a site was required possessing homogeneous flow, preferably when the wind was from the prevailing south-westerly direction. A site was located at Lammefjord, a reclaimed fjord on the Danish island of Zealand. Lammefjord is amongst the flattest terrain in Denmark. Much of the land lies slightly below sea-level and because of difficulties with drainage, most of the buildings are grouped together on areas that were above water level prior to reclamation. The remainder of the land is used for agriculture, predominantly with root crops such as carrots and potatoes. The location of the measuring masts is indicated in Figure 1. To the south-east and north-west lie the towns of Fårevejle Stationby and Faarvejle respectively. To the south-east (Fårevejle Stationby) the nearest buildings are about 1 km from the measuring masts whilst in the opposite direction (Fårevejle) the distance is about 0.5 km. A road connects the two towns and this passes about 150 m to the north-east of the masts. Apart from the road, the terrain to the north-east is open with the nearest buildings about 800 m away. To the south and south-west, the terrain is flat and completely unobstructed for a distance of between 2.5 and 3.0 km. Between the south-west and north-west the terrain is identical but the fetch reduces sharply to a little over 1 km. The old sea bed is bounded by a drainage canal, beyond which the terrain rises steeply, especially between west and north-west. Acknowledgements: The Lammefjord measurements were partly funded by the CEC, Directorate- General for Science, Research and Development under contract number EN-3W-002-DK(B). Preparation of the CD-ROMs has been partially supported by the EU funded JOULE project "Measuring and modelling in complex terrain", contract number JOUR-0067-C(MB).

Measurement system
An array of cups, vanes and one sonic anemometer were sampled by a PC. Data were stored on a magneto-optisk WORM drive. Data were recorded at 16 Hz for the sonic and 8 Hz for the cups and vanes. Measuring Masts: Since the data are primarily intended for wind turbine research, the aim was to instrument a vertical plane corresponding to that formed by the rotor of a medium sized wind turbine. This was accomplished by using three measuring masts erected so as to form a vertical plane 30 x 30m, perpendicular to the prevailing wind. An array of cup anemometers and wind direction vanes were distributed over this area as shown in Figure 2. A sonic anemometer was mounted at a height of 46m. In relation to the vertical plane formed by the three masts, a 10m mast was erected 15m upstream (in the prevailing wind direction). This was instrumented with a cup anemometer and a wind vane at 10m height. The masts are referred to as masts 1-4, with the mast to the left in Figure 2 as number 1, the mast in the centre as 2 and that to the right as mast 3.The upstream 10m mast is mast 4. The following table gives the (x,y) co-ordinates of the instruments mounted on each mast (including boom offset) in a co-ordinate system with x in the plane of the masts pointing towards north-west (319 deg) and y pointing perpendicular to the mast plane towards the south-west (229 deg). Dimensions are in meters. Mast x y Instrumentation 1 0.0 0.0 cups(3), vanes(3), sonic, climatology 2 20.0 0.0 cups(2), vanes(2) 3 30.0 0.0 cups(3), vanes(3) 4 22.7 15.3 cup, vane ("upstream" mast) Instrument station numbers have been assigned according to the

following table. Station Mast Height Instrumentation sonic 1 46 Sonic (X, Y, Z, T) 1 1 10 Cup and vane (cos, sin) 2 1 20 Cup and vane (cos, sin) 3 1 30 Cup and vane (cos, sin) 4 2 10 Cup and vane (cos, sin) 5 2 30 Cup and vane (cos, sin) 6 3 10 Cup and vane (cos, sin) 7 3 20 Cup and vane (cos, sin) 8 3 30 Cup and vane (cos, sin) 9 4 10 Cup and vane (cos, sin) 10 1 various Cup Climatological Measuring System: An independent climatological measuring system was also installed, with all the relevant sensors mounted on mast 1. This instrumentation comprised: cup anemometers at 3, 10 and 45m wind direction vane at 10m global radiation relative humidity (horse-hair hygrometer) absolute temperature at 10m difference temperature 10m - 2m difference temperature 40m - 10m barometric pressure Observations were recorded every 10 minutes using an Aanderaa battery powered data logging system. Note that with the exception of the cup anemometer speed, all recorded observations are instantaneous values once per 10 minutes. Cup mean speed is derived by counting pulses over the 10-minute period. Cup Anemometer: The cup anemometers used were the Risoe model 70, fitted with carbon fibre cups. This instrument has a length constant of 1.7m. A two-pole magnet driven by the cup shaft is used to open and close a reed-contact switch, producing two pulses per revolution. Wind speed was derived using the Risoe P1225 Wind Speed Transmitter. This device is a microprocessor controlled frequency to voltage converter. The output voltage is updated on each incoming pulse such that the signal is proportional to the frequency derived from the preceding two pulses. Before installation, but following a two month “run-in” period, the cup anemometers were calibrated in a wind tunnel. Re-calibration of the cup anemometers after the completion of the experiment showed that the instrument characteristics had remained essentially constant. Individual calibrations have been used for each of the cup anemometers. Wind speed signals were sampled at 16 Hz through a first order RC filter with a -3db frequency of 35 Hz. Each two consecutive 16 Hz scans were averaged so that the data are stored at 8 Hz.

Acknowledgements
Michael Courtney, Risø National Laboratories, Denmark



Nominal turbulence vs. wind speed.

Site = Lavrio, CRES, Greece

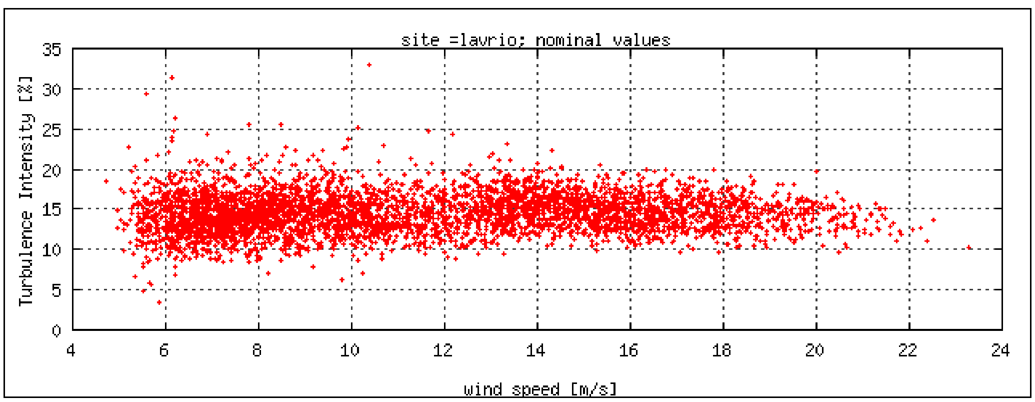
Site code **Lavrio**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	6	4
Number of sonics / height of met. Mast.	1	40 & 40 m
Hours of measurements / frequencies	759	1 & 8 Hz

Project motivation
The main objective of the project was to identify the mountainous terrain effects in the operation, safety and reliability of wind turbines. The methodology designed for the project included site wind and wt on site characterisations and complex terrain parameter (of importance to wind turbine operation) identification through experimental and analytical work.

Measurement system
Wind structure measurements on mountainous terrain: the 3D wind inflow to a wind turbine rotor was measured by CRES with a number of standard cups and fast sonic anemometers installed on a system of masts at CRES' complex terrain wind turbine Test Station. The wind structure measurements were coupled to the response of a 110kW stall regulated wt (W110XT) through load and power measurements.

Acknowledgements
A.N.Fragoulis, C.R.E.S, Greece.



Nominal turbulence vs. wind speed.

Site = Lysekil, Sweden

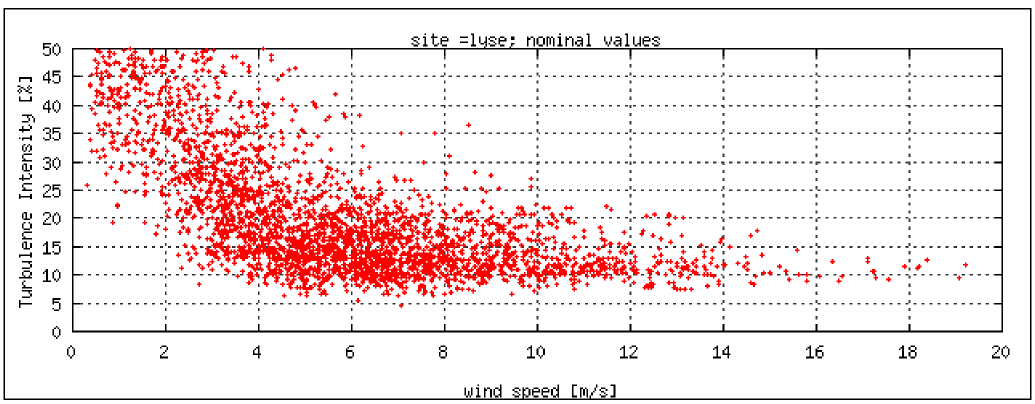
Site code **Lyse**

Dominating terrain/ orography	Coastal	Mountain
Number of masts / wind turbines	1	2
Number of channels with wind speed / wind direction	12	12
Number of sonics / height of met. Mast.	0	66 m
Hours of measurements / frequencies	3355	Appr. 1 Hz

Project motivation
At Lyse Wind Power Station the NWP400 wind turbine was erected in 1992. The wind turbine is a two-bladed, upwind machine with a hub height of 40 m, and a rotor diameter of 35 m.

Measurement system
Lyse wind power station is situated at an artificial island created around two islets. On each of the rocky islets wind turbines are erected. The above mentioned NWP400 to the north and a Bonus 400 kW MkII to the south. Between the two turbines a 66 m high meteorological tower is situated, which is equipped with wind speed and direction sensors of the MIUU type (Lundin et al., 1990) at 7 levels. At the uppermost 5 levels two anemometers are placed at each level. Temperature profile is also recorded. All measurements are sampled with 1 Hz and stored on 1 GB streamer tape.

Acknowledgements
Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Maglarp, Sweden

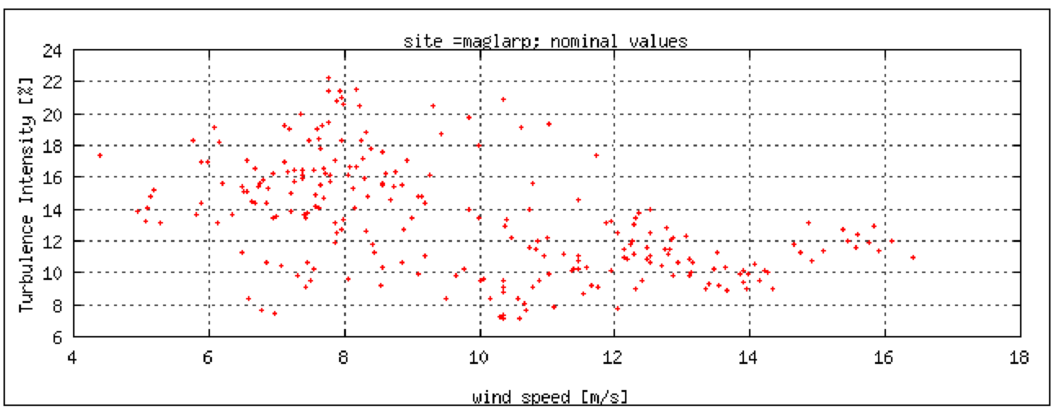
Site code **Maglarp**

Dominating terrain/ orography	Rural	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	84 m
Hours of measurements / frequencies	41	20 Hz

Project motivation
The project has been initiated as part of a larger measurement program on the WTS-3 wind turbine. The site is located on a low sloping hill in slightly rolling farmland.

Measurement system
20 Hz data are recorded at 2 levels (13 & 84 m) on a 120 m mast during one month. The instrumentation consists only of 3-component hotwires.

Acknowledgements
Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Middelgrunden, Denmark

Site code **Midgrund**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	0	45 m
Hours of measurements / frequencies	2075	5 Hz

Project motivation

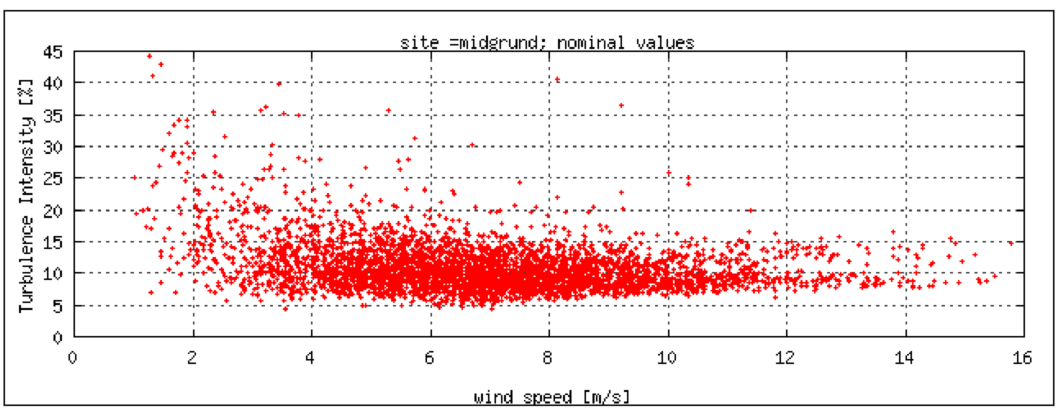
The meteorological mast at Middelgrunden was established in 1997 in order to provide wind and turbulence characteristics for the wind farm which was constructed in the autumn 2000. Middelgrunden is an atypical Danish offshore wind energy site in two respects: 1. It is east of the island of Zealand in the Øresund and has a relatively short sea fetch in most directions (from 2.1 km at 210° to a maximum of approximately 20 km across the Øresund and in north-south directions). 2. It is east of the city of Copenhagen which introduces large roughness elements which are expected to significantly influence particularly turbulence characteristics at the site. The Middelgrunden meteorological mast (55° 42.1 N 12° 39.45 E) was installed in October 1997 and ran until January 2000 when it was destroyed by a ship. At the time of writing (Autumn 2000) plans were underway to re-instrument the mast and to install mains electricity and a fibre optic link from the nearby offshore wind farm.

Measurement system

The mast is a triangular tapered structure in 7.5 m sections. Booms are oriented 94° and 274° with all cup anemometers installed on the westerly booms. Wind speeds are measured at 7.9, 27.7 and 48 m from the base of the mast at Middelgrunden but because of the foundations the actual height above mean sea level is approximately 2.5 m higher. Therefore the wind speed reference levels are 10, 30 and 50 m above mean sea level. Data acquisition is via Risø's DAQ system collected by mobile phone link. The system is powered by a wind turbine/battery system.

Acknowledgements

Rebecca Barthelmie, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Mt. Tsukuba, Japan

Site code **Mttsukub**

Dominating terrain/ orography	Forest	Mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	0
Number of sonics / height of met. Mast.	0	30m
Hours of measurements / frequencies	2410	4 Hz

Project motivation

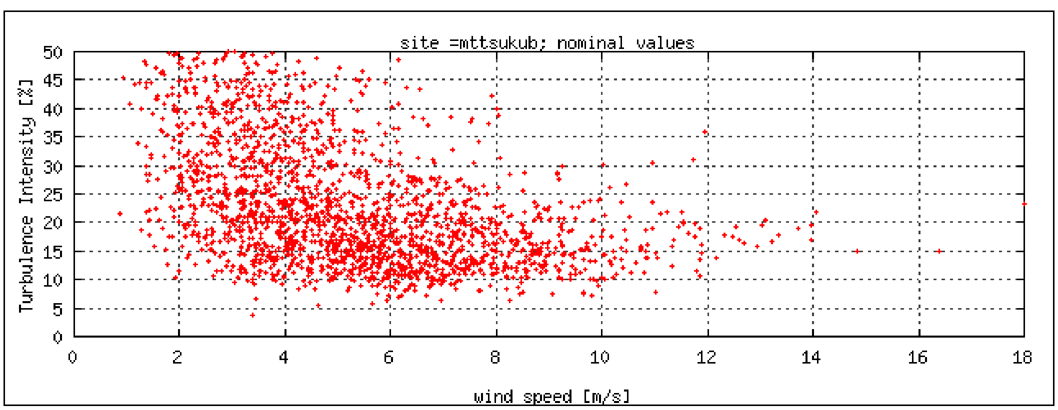
The Tsukuba city office have plan to construct a 750kw wind turbine in Mt. Tsukuba. In the region of Mt. Tsukuba, the famous strong wind called ”Tsukuba-Oroshi” blows in winter. In order to estimate the wind energy potential in this region, they started to measure wind velocities with the aid of NEDO’s Field Test Project of Wind Turbine Generation.

Measurement system

The measurement system consists of one meteorological mast. Wind mesurements are carried out using a ultrasonic anemometer, two cup anemometers and two wind vanes. The height of the mast was 30 m. Only the wind data obatained by the ultrasonic anemometer is available because other data were sampled with lower sampling frequencies than that required in the database.
Measurements by the ultrasonic anemometer were sampled with 4 Hz. There is no commercial power supply near the site. Two pairs of twelve batteries for large trucks were used to operate the ultrasonic anemometer and a notebook computer used as a data logger.

Acknowledgements

Tetsuya Kogaki, AIST, Japan



Nominal turbulence vs. wind speed.

Site = Näsudden, Gotland, Sweden

Site code **Nasudden**

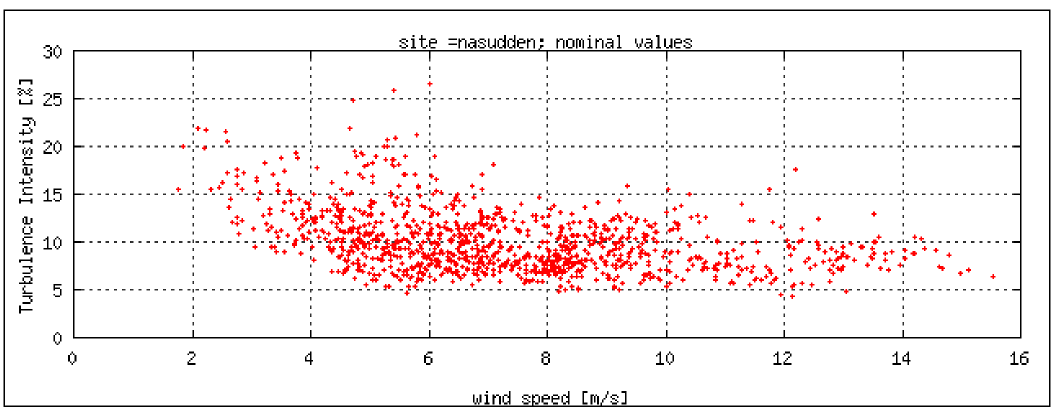
Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	3 & 5	3 & 5
Number of sonics / height of met. Mast.	0	135 m
Hours of measurements / frequencies	140 & 2870	20 & 1 Hz

Project motivation
Meteorological measurements from Nasudden site at Gotland, Sweden.

Measurement system
20 Hz data at two or three levels on a 145 m tower during several campaigns of 2-4 weeks.

Comments
Preliminary measurements are recorded with hotwires (140 hours). Sh1, sh2, sh3 are derived speeds and dh1, dh2, dh3 are derived directions from preliminary measurements.

Acknowledgements
Mikael Magnusson & Hans Bergström, Uppsala University and Ingemar Carlén Teknikgruppen AB, Sweden.



Nominal turbulence vs. wind speed- cup signals only.

Site = NTK1500, Tjæreborg, Denmark

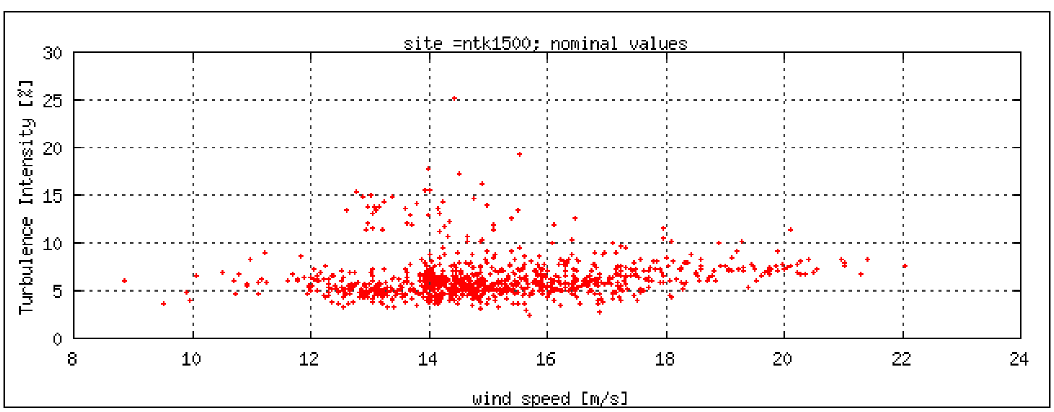
Site code **Ntk1500**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2	1
Number of sonics / height of met. Mast.	0	60 m
Hours of measurements / frequencies	151	40 Hz

Project motivation
The aim of the measurement project has been to verify the characteristics of the NEG-Micon NM1500 prototype wind turbine. The terrain around the wind turbine is flat and in the measurement sector there no roughness elements of importance. The terrain south-west of the test site (the measurement sector) is a march area with a roughness length less than 0.1 m out to a distance 3 km in the measurement sector. The wind turbine NTK1500 manufactured by Nordtank A/S are located together with 3 other prototype turbines 2MW owned by Vestkraft, 1.5 MW Vestas and 1.0 MW Bonus. Note:Time series recorded as part of the 2MW measurement programme are available for the site_code=tjare.

Measurement system
The height of the meteorological mast is 60m, which contains a standard measurement setup necessary for making a standard load measuring program. The instrumentation includes 2 cup anemometers and one vane together with temperature, pressure and rain detection system. The DAQ recording software has been used for recording and storing time series at a frequency of 40 Hz.

Acknowledgements
Søren O.Lind, Risø National Laboratories, Denmark



Nominal turbulence vs. wind speed.

Site = Oak Creek wind farm, Tehachapi, USA

Site code **Oakcreek**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	2	3
Number of channels with wind speed / wind direction	8	3
Number of sonics / height of met. Mast.	2	80 m
Hours of measurements / frequencies	1825	8 & 16 Hz

Project motivation

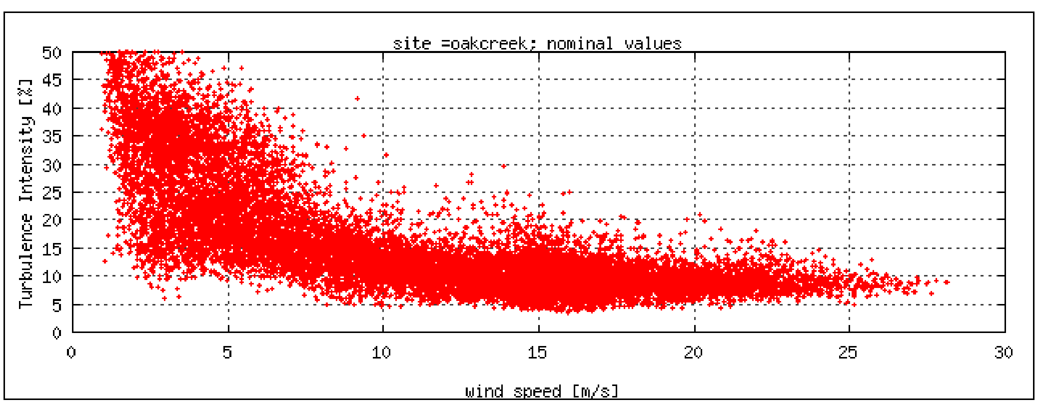
The objective of the Oak Creek project is to conduct a combined experimental and theoretical investigation of blade-, rotor- and tower loads caused by extreme wind load conditions occuring during normal operation as well as in stand still situations (where mean wind speeds exceeds the cut-out wind speed), with the purpose of establishing an improved description of the ultimate loading of three bladed pitch- and stall controlled wind turbines.

Measurement system

The measurements are performed in a wind farm situated at a high wind site in Oak Creek, near Tehachapi in California. The wind farm consists of wind turbines erected on a ridge in a very complex terrain. The prevailing wind direction is 320 degrees and thus perpendicular to the ridge. The wind field is measured from two 80 m high meteorological towers erected less than one rotor diameter in front of one of the wind turbines (in the direction of the prevailing wind direction), and the distance between the two meteorological towers is 25.5 m, corresponding to 0.58 rotor diameters. Thus, detailed information of the inflow field to the particular turbine rotor is provided. The instrumentation of the meteorological towers included sensors at multiple levels. In general, all specified instrument heights are given relative to the base of the relevant meteorological tower.

Acknowledgements

Søren M. Petersen, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Rødsand, Gedser Vest, Denmark

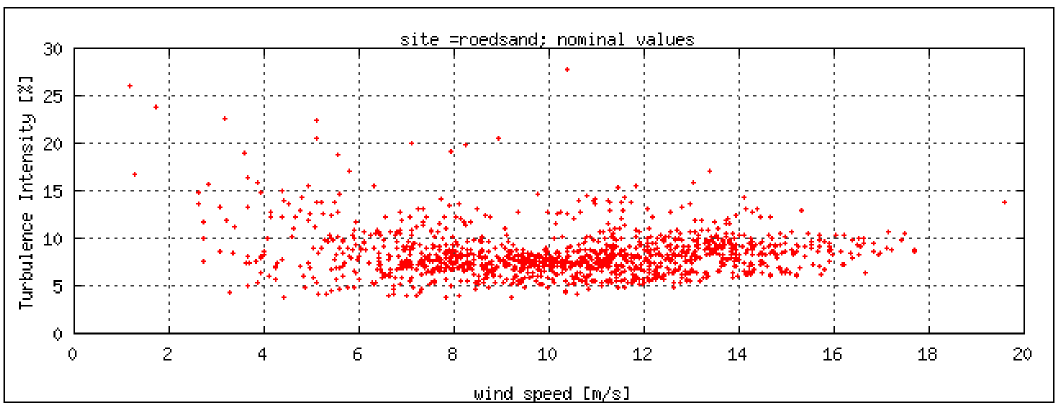
Site code **Roedsand**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	1	45 m
Hours of measurements / frequencies	41	5 & 20 Hz

Project motivation
Characterising wind and turbulence for offshore wind energy development.

Measurement system
A 48 m high lattice mast was erected at Rødsand (off-shore), Gedser Syd, Denmark. This mast has been instrumented with 3 cup anemometers, 1 vane and 1 sonic anemometer together with several thermometers.

Acknowledgements
Rebecca Barthelmie, Risø National Laboratories and SEAS, Denmark.



Nominal turbulence vs. wind speed.

Site = San Jose, Azores, Portugal

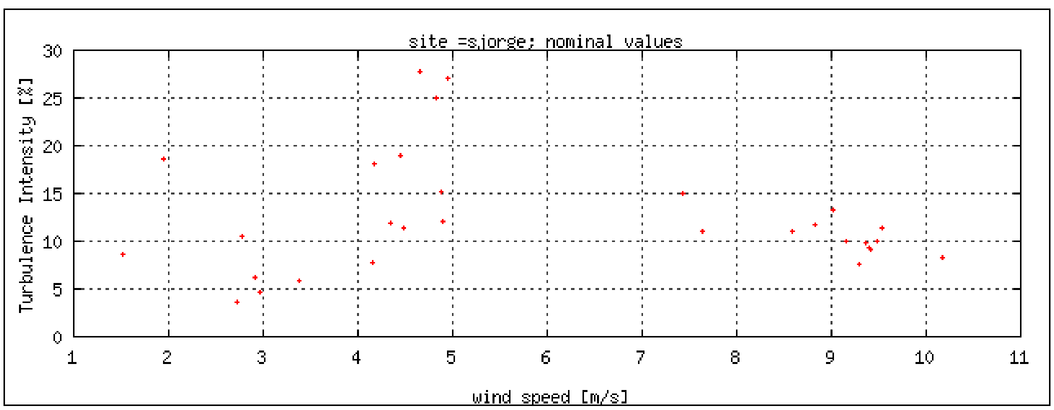
Site code **Sjorge**

Dominating terrain/ orography	Coastal	Mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	1	27 m
Hours of measurements / frequencies	5	40 Hz

Project motivation
Development and validation of wind park and local grid detailed dynamic models (INPark).

Measurement system
The measurement system was based on one 9200 PLUS NRG data logger with NRG#40 cup anemometers and NRG#200P wind vane as transducers, and the 3D wind components were obtained through a solent research symmetric head sonic anemometer, being the data acquisition system a GH-Garrad Hassan T-DAS operated by the GH-MON software.

Acknowledgements
Ana Estanqueiro, INETI, Portugal



Nominal turbulence vs. wind speed.

Site = Skipheya, Frøya, Norway

Site code **Ski**

Dominating terrain/ orography	Coastal	Hill
Number of masts / wind turbines	3	2
Number of channels with wind speed / wind direction	17	1
Number of sonics / height of met. Mast.	0	100 m
Hours of measurements / frequencies	13174	0.85 Hz

Project motivation

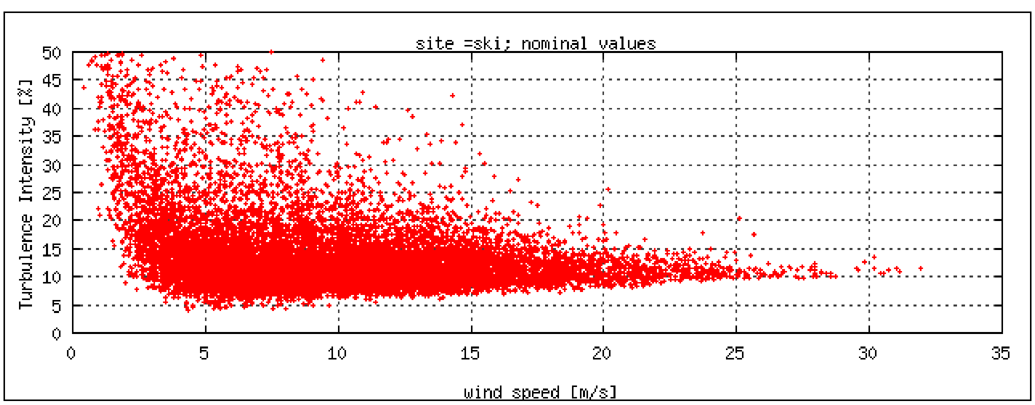
The station was build as a part of the Norwegian Wind Energy Programme in 1980. The purpose was to study the wind structure in details. Particularly, a database for high wind speed condition was desired. Data were originally intended for wind energy production; the dimension of the masts corresponds to a large WECS. The station should also serve as a reference station for other measurement stations in the region. Together with a fourth mast 4 km further west (Sletringen) the station has provided data for calculation of dynamic wind loads on off-shore constructions.

Measurement system

The measurement system consists of 3 meteorological masts (100, 100 and 45 m) placed in a triangle 80-180 metres apart. Ten-minute average of wind speed and direction have been recorded since 1982. From 1988, the logging frequency has been 0.85 Hz. 40-60 channels have been recorded continuously. In a 45 m mast at Sletringen, data has been recorded for some periods since 1988.

Acknowledgements

Jørgen Løvseth, NTNU, Norway



Nominal turbulence vs. wind speed.

Site = Sky River wind farm (location V27) in Tehachapi, USA

Site code **Skyv27**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	4	2
Number of sonics / height of met. Mast.	1	42 m
Hours of measurements / frequencies	164	8 & 32 Hz

Project motivation

Verification of the structural integrity of a wind turbine involves analysis of fatigue loading as well as ultimate loading. With the trend of persistently growing turbines, the ultimate loading seems to become relatively more important. For wind turbines designed according to the wind conditions prescribed in the IEC-61400 code, the ultimate load is often identified as the leading load parameter.

The objective of the Oak Creek project is to conduct a combined experimental and theoretical investigation of blade-, rotor- and tower loads caused by extreme wind load conditions occuring during normal operation as well as in stand still situations (where mean wind speeds exceeds the cut-out wind speed), with the purpose of establishing an improved description of the ultimate loading of three bladed pitch- and stall controlled wind turbines.

Measurement system

The measurements are performed in a wind farm situated at a high wind site in Oak Creek, near Tehachapi in California. The wind farm consists of wind turbines erected on a ridge in a very complex terrain. The prevailing wind direction is 320 degrees and thus perpendicular to the ridge. The turbines are closely spaced - the inter turbine spacing is 53 m, corresponding to approximately 1.2 rotor diameters. The wind turbines are tree bladed NEG-Micon 650 kW stall regulated turbines with hub heights and rotor diameters equal to 55 m and 44 m, respectively.

The wind field is measured from two 80 m heigh meteorological towers erected less than one rotor diameter in front of one of the wind turbines (in the direction of the prevailing wind direction), and the distance between the two meteorological towers is 25.5 m, corresponding to 0.58 rotor diameters. Thus, detailed information of the inflow field to the particular turbine rotor is provided.

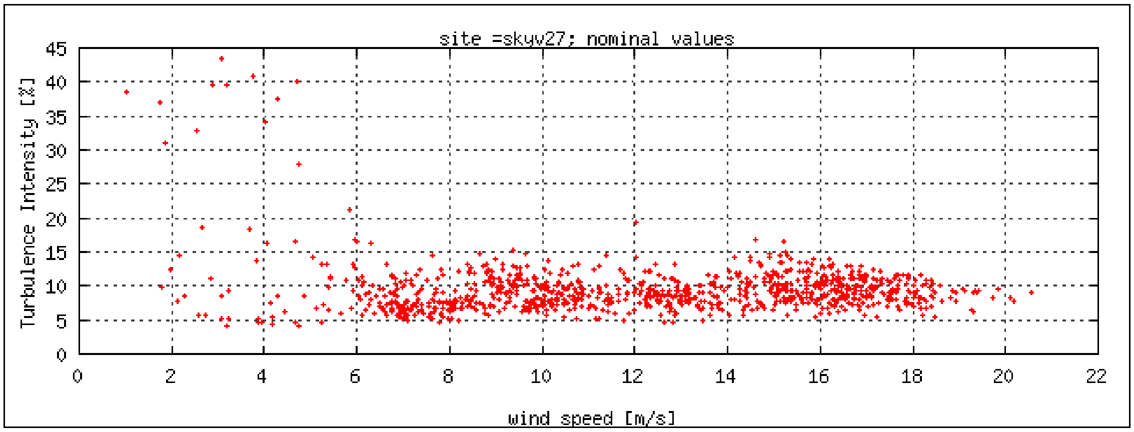
The instrumentation of the meterological towers included sensors at multiple levels. Basically, similar instruments on each of the two masts have been installed in roughly the same level relative to the terrain level.

The monitoring system is running continously, and the data are reduced and stored as 10-minutes statistics suplemented with intensive time series recordings covering periods where the mean wind speeed exceeds a specified threshold (15 m/s). Consequently, there are time gaps in the the time series. The monitoring sample rate is 32 Hz.

Detailed information on the individual sensors is provided from the Master Sensor List. In general, all specified instrument heights are given relative to the base of the relevant meterological tower.

Acknowledgements

Søren Markkilde Petersen, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Sky River wind farm (location V39) in Tehachapi, USA

Site code **Skyv39**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2	2
Number of sonics / height of met. Mast.	1	43 m
Hours of measurements / frequencies	105	8 & 32 Hz

Project motivation

Verification of the structural integrity of a wind turbine involves analysis of fatigue loading as well as ultimate loading. With the trend of persistently growing turbines, the ultimate loading seems to become relatively more important. For wind turbines designed according to the wind conditions prescribed in the IEC-61400 code, the ultimate load is often identified as the leading load parameter.

The objective of the Oak Creek project is to conduct a combined experimental and theoretical investigation of blade-, rotor- and tower loads caused by extreme wind load conditions occuring during normal operation as well as in stand still situations (where mean wind speeds exceeds the cut-out wind speed), with the purpose of establishing an improved description of the ultimate loading of three bladed pitch- and stall controlled wind turbines.

Measurement system

The measurements are performed in a wind farm situated at a high wind site in Oak Creek, near Tehachapi in California. The wind farm consists of wind turbines erected on a ridge in a very complex terrain. The prevailing wind direction is 320 degrees and thus perpendicular to the ridge. The turbines are closely spaced - the inter turbine spacing is 53 m, corresponding to approximately 1.2 rotor diameters. The wind turbines are tree bladed NEG-Micon 650 kW stall regulated turbines with hub heights and rotor diameters equal to 55 m and 44 m, respectively.

The wind field is measured from two 80 m heigh meteorological towers erected less than one rotor diameter in front of one of the wind turbines (in the direction of the prevailing wind direction), and the distance between the two meteorological towers is 25.5 m, corresponding to 0.58 rotor diameters. Thus, detailed information of the inflow field to the particular turbine rotor is provided.

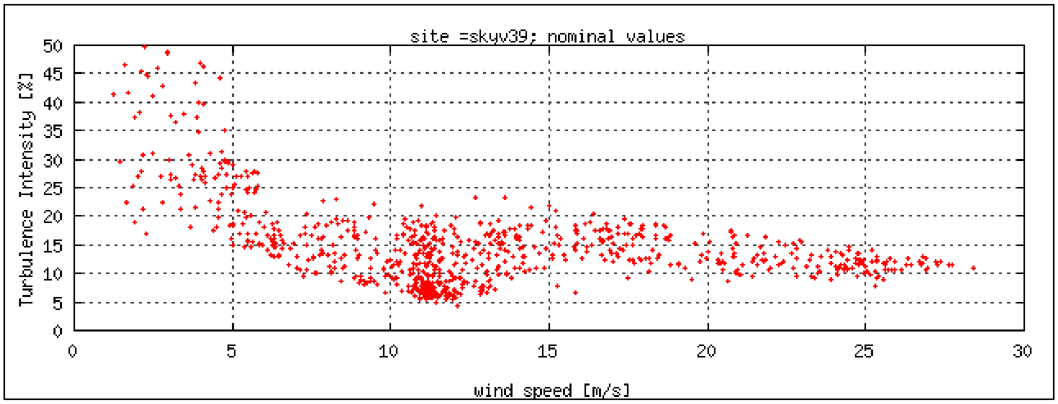
The instrumentation of the meterological towers included sensors at multiple levels. Basically, similar instruments on each of the two masts have been installed in roughly the same level relative to the terrain level.

The monitoring system is running continously, and the data are reduced and stored as 10-minutes statistics suplemented with intensive time series recordings covering periods where the mean wind speeed exceeds a specified threshold (15 m/s). Consequently, there are time gaps in the the time series. The monitoring sample rate is 32 Hz.

Detailed information on the individual sensors is provided from the Master Sensor List. In general, all specified instrument heights are given relative to the base of the relevant meterological tower.

Acknowledgements

Søren Markkilde Petersen, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Sletringen, Norway

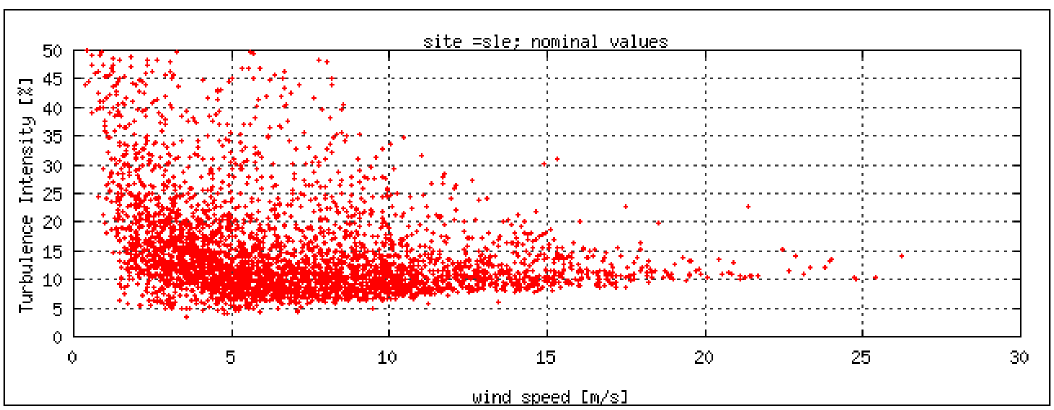
Site code **Sle**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	5	1
Number of sonics / height of met. Mast.	0	45 m
Hours of measurements / frequencies	3736	Appr. 0.85 Hz

Project motivation
The station was build as a part of the Norwegian Wind Energy Programme in 1980. The purpose was to study the wind structure in details. Particularly, a database for high wind speed condition was desired. Data were originally intended for wind energy production; the dimension of the masts corresponds to a large WECS. The station should also serve as a reference station for other measurement stations in the region. Together with a fourth mast 4 km further west (Sletringen) the station has provided data for calculation of dynamic wind loads on off-shore constructions.

Measurement system
Lattice tower, 45 m. Booms at heights: 46, 42, 20, 10 and 5 m. Cup anemometers at all heights. Vane at 46 m. Temperature measurements at 45m, 5m, and sea.

Acknowledgements
Jørgen Løvseth, NTNU, Norway.



Nominal turbulence vs. wind speed.

Site = Sprogø, Storebælt, Denmark

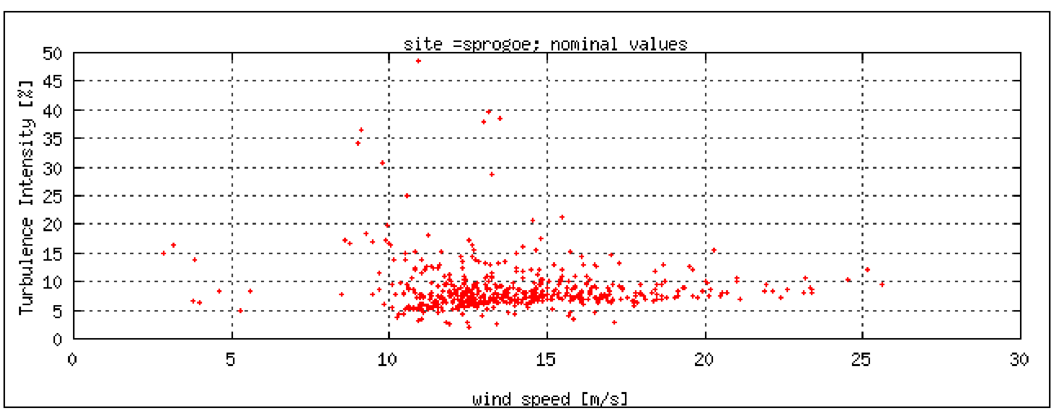
Site code **Sprogoe**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	3	70 m
Hours of measurements / frequencies	527	2 & 10 Hz

Project motivation
With the purpose of supporting determination of the design wind loads on the East Bridge of The Great Belt Link, Risoe National Laboratory has made an investigation of the structure of the turbulence at the height of the suspended span on the suspension bridge. The experiment: In the period extending from June 1990 to the middle of June 1991 omni-directional anemometers, mounted on 70 m high meteorological towers at Sprogø, have measured the wind velocity vectors at three horizontally displaced points. The Measuring Site: The measurements were recorded on a small island, Sprogø, located in the middle of The Great Belt between Funen and Zealand. The meteorological masts were erected on the eastern side of some flow obstacles present on the island (hill and buildings), which enables free access for northern, eastern and southerly wind directions.

Measurement system
Measuring mast: The measuring setup consists of 2 meteorological masts each with a height of 70 m and 40 m horizontal separation. A 15 m horizontal boom is mounted symmetrically on top of the second mast in such a way that the whole construction has the form of the letter “T”. Instrumentation: The basis for the coherence measurements consists of an array of 3 sonic anemometers - mounted at a height of 70 m. Close to each sonic anemometer is installed a cup anemometer, and furthermore a single wind vane is mounted in the centre of the “T” boom. The data acquisition system: The data acquisition system is based upon a personal computer (PC) running the Risø DAQ data acquisition software. Signals are sampled continuously with time series data being logged to disk when certain wind speed and wind direction criteria are satisfied. Data scanning and recording: All data are sampled with 40 Hz. For sonic anemometer channels the stored data is reduced to 10 Hz by block averaging. Similarly, wind vane and cup anemometer signals are reduced to 2 Hz.

Acknowledgements
Søren Larsen, Risø National Laboratories and A/S Storebæltsforbindelsen, Denmark.



Nominal turbulence vs. wind speed.

Site = Tarifa, Spain

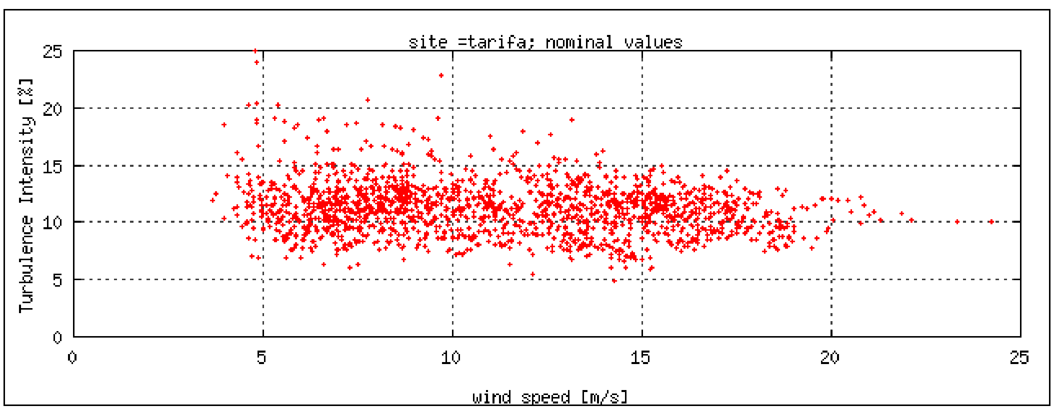
Site code **Tarifa**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	8	2
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	280	2 Hz

Project motivation
The primary goal was to investigate of design aspects and design options for wind turbines operating in complex terrain environments within COMTERID project.

Measurement system
The measurements system consist of two meteorological masts, mast n§1 located towards NNW direction and 15 degrees from the north, mast n§2 located towards South direction and 190 degrees from the north The measurements system was based on Garrad Hassan acquisition system. The system operation was primary focusing on recording structural loads including a number of meteorological channels. Data recording frequency was 40 Hz and duration of 600 seconds.

Acknowledgements
Jorge Navarro, Dept. of Renewable Energy, Ciemat, Madrid, Spain



Nominal turbulence vs. wind speed.

Site = Tarifa-2, wind measured near the Nordtank windfarm, Tarifa, Spain

Site code **Tarifa_2**

Dominating terrain/ orography	Pastoral	Hill
Number of masts / wind turbines	1	12
Number of channels with wind speed / wind direction	2	2
Number of sonics / height of met. Mast.	2	45 m
Hours of measurements / frequencies	2075	5 Hz

Project motivation

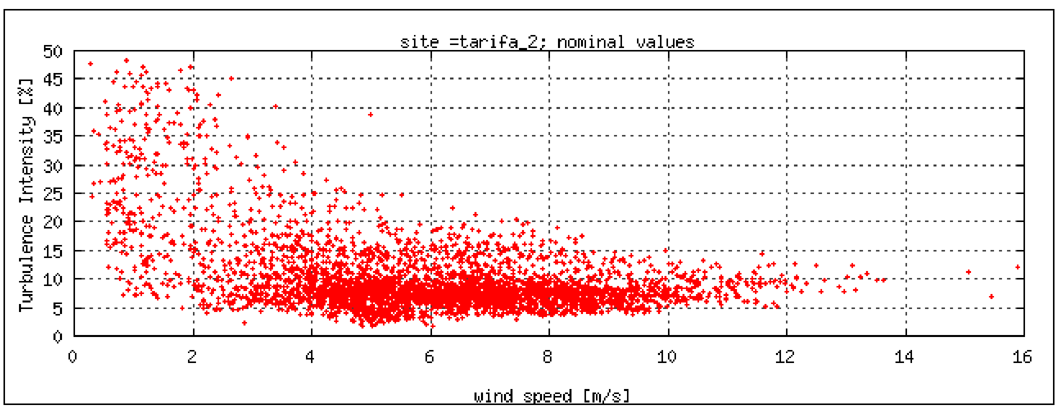
It has been known for many years that under certain climates stall-regulated wind turbines will stall at a lower level than expected - this is known as double-stall. In this project the wind climate was investigated at Tarifa in south Spain near Gibraltar where double-stall has often been observed. The object was to investigate the parameters that are believed to cause double-stall. The three turbulence components u, v and w are measured with sonic anemometer and stored as time-series. Furthermore, weather parameters like temperature, pressure, humidity and precipitation are stored as 10-minute average values.

Measurement system

The measurement system consists of 2 sonic METEK USA-1 anemometers located on a mast in 20 and 30 m height. Weather parameters are collected 3 m above ground level. The prevailing wind directions are east and west. 12 wind turbines and the mast are located on a north south going rim. Consequently, the flow at the mast will not be disturbed by the turbines. Data recording frequency was 20 Hz with the sonics and all data are stored in 600 sec files. File name indicates beginning of 10 minutes sampling period: MMDDHHMM. E.g. 01091610 means 9 January, 600 seconds sampled from 4.10 p.m.

Acknowledgements

Torkild Christensen, Tech-wise A/S (former Elsamprojekt A/S), Denmark.



Nominal turbulence vs. wind speed.

Site = Tjæreborg, 2MW, 60 m wind turbine, Spain

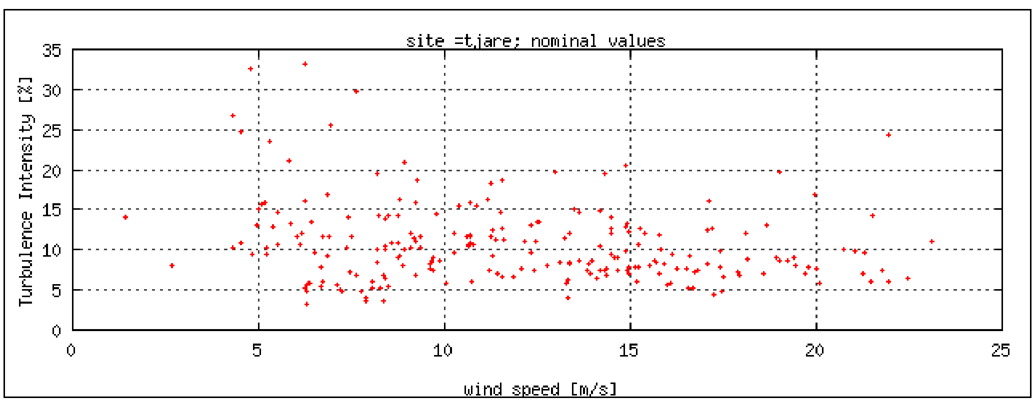
Site code **Tjare**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	12	6
Number of sonics / height of met. Mast.	0	90 m
Hours of measurements / frequencies	64	25 Hz

Project motivation
The primary goal was to design and build a 2MW wind turbine at Tjaereborg, Esbjerg. This project was accomplished with an intensive measuring programme where both mechanical loads and the wind climate on the site was measured - and analysed. The wind data were recorded as part of this measurement programme.

Measurement system
The measurement system consists of 2 meteorological mast, mast no.1 was placed in front and mast no.2 behind the wind turbine - referring to the dominant wind sector. The measurements system was based on two HP data loggers and the data was transferred to a central computer (HP operating HP-Basic with home developed data handling routines and programs). The system operation was primarily focusing on recording structural loads included a number of meteorological channels. Data recording frequency 25 Hz and duration = 184, 600 or 3600 seconds. Only data with a duration of 600 seconds or more are used.

Acknowledgements
Peter Christiansen, Tech-wise A/S (former Elsamprojekt A/S), Denmark.



Nominal turbulence vs. wind speed.

Site = Toboel, Ribe, Denmark

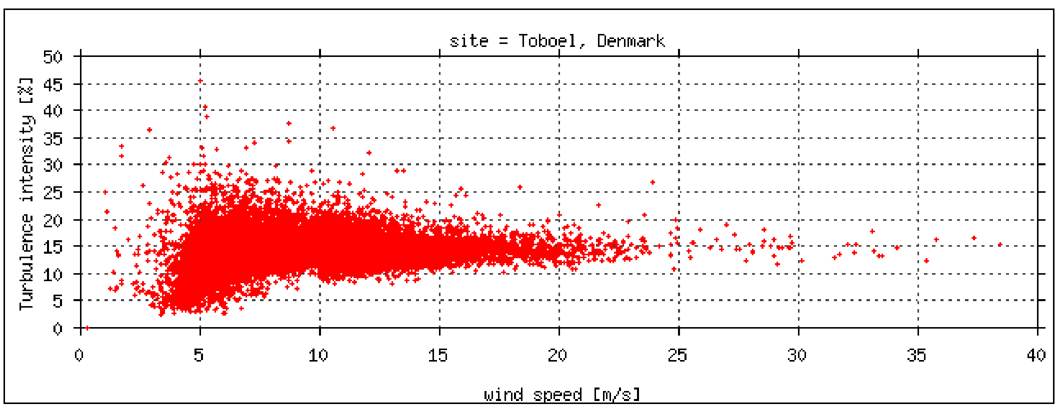
Site code **Toboel_1 & toboel_2**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	2	2
Number of channels with wind speed / wind direction	5	3
Number of sonics / height of met. Mast.	1	49 m
Hours of measurements / frequencies	2071	8 & 32 Hz

Project motivation
The aim of the measurement project has been to verify the characteristics of the two NEG-Micon prototype wind turbines during various tests. The terrain around the wind turbine is flat and in the measurement sector there are no roughness elements of importance.

Measurement system
The height of the meteorological mast is 49m which contains a standard measurement setup necessary for making a standard load measuring program. The instrumentation includes five cup anemometers, one sonic anemometer and one vane together with temperature, pressure and rain detection system. The DAQ recording software has been used for recording and storing time series at a frequency of 32 Hz.

Acknowledgements
Søren Markkilde Petersen, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Toplou, Crete, Greece

Site code **Toplou**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2	1
Number of sonics / height of met. Mast.	1	40 m
Hours of measurements / frequencies	172	1 & 8 Hz

Project motivation

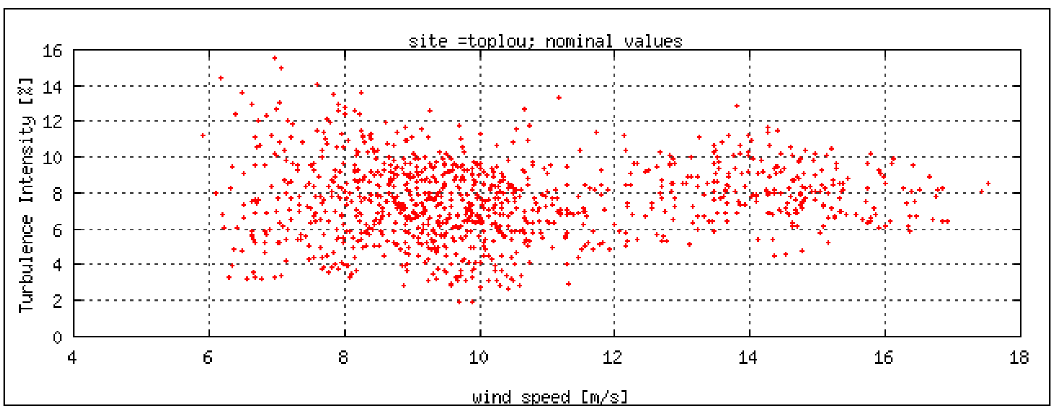
The main objective of the project is to develop a cost effective and easy to apply method for further assessment of fatigue loading effects through measurements. Its simplicity and robustness will enable easy application by industries. Obtained fatigue load “footprints” will be able to back up findings as derived from theoretical research work and will contribute to improved specifications on wind farm and mountainous terrain operation in international guidelines.

Measurement system

Wind and wind turbine power and loads measurements on mountainous terrain at Toplou site, in Crete. Wind measurements are carried out using cups and vanes and a sonic anemometer for determining the 3D characteristics of the wind and these measurements are coupled to the response of a 500kW stall regulated wt (TW-500) through load and power measurements.

Acknowledgements

E.F.Morfiadakis, C.R.E.S, Greece.



Nominal turbulence vs. wind speed.

Site = Tsukuba, Japan

Site code **Tsukuba**

Dominating terrain/ orography	Rural	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	1	1
Number of sonics / height of met. Mast.	0	15 m
Hours of measurements / frequencies	1355	1 Hz

Project motivation

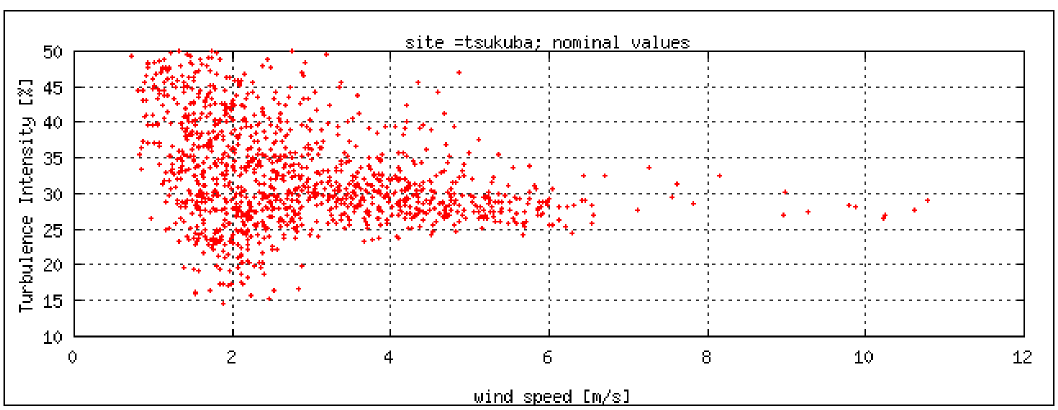
The wind turbine WINDMEL-II (WIND turbine at Mechanical Engineering Laboratory) has been erected by MEL in 1994 within the framework of the New Sunshine (NSS) project aiming at researching and developing various renewable energy technologies. The objective is to evaluating a flexible design concept of wind turbines. The WINDMEL-II (Two blades, diameter 15m) was designed based on a flexible wind turbine technology such as variable speed operation, teetered hub, soft-designed tower, and AC-DC-AC link.

Measurement system

The WINDEMEL-II has been elected in the Tsukuba Research Centre No.2, Agency of Industrial Science and Technology (AIST). The measurement system consists of 1 meteorological mast, which lies 37.5 m to the north-east of the WINDMEL-III. The height of the mast was 15.14 m, which is same as the hub height of the WINDMEL-II. Wind measurements are carried out using a propeller anemometer to evaluate the performance of the WINDMEL-II. The measurement data are transmitted from the sensors to the data logger by an optical fibre cable. All measurements are sampled with 1 Hz.

Acknowledgements

Tetsuyo Kogaki, MEL, Japan.



Nominal turbulence vs. wind speed.

Site = Ütlängan, Sweden

Site code **Utlangan**

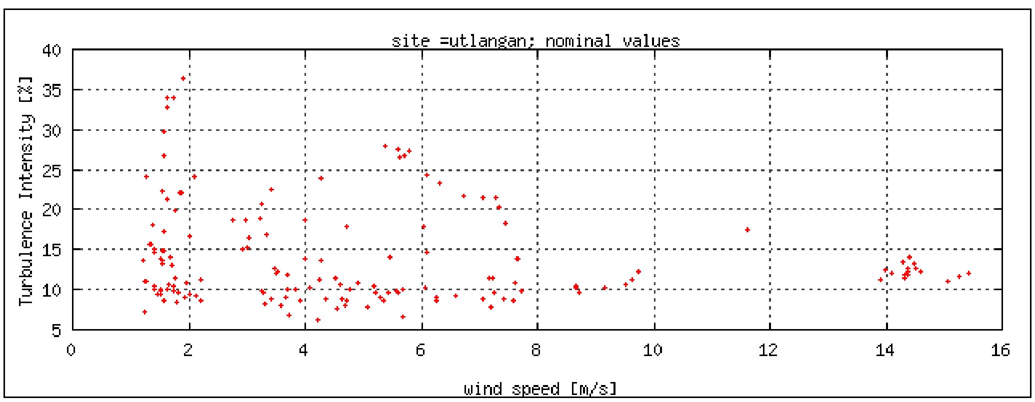
Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	22.5 m
Hours of measurements / frequencies	90	20 Hz

Project motivation
This site is a small island in an archipelago.

Measurement system
20 Hz data at two levels on a 20 m tower for one month.

Comments
All measurements are recorded with hotwires. Sh1, sh2 are derived speeds and dh1, dh2 are derived directions.

Acknowledgements
Mikael Magnusson and Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Vindeby off-shore wind farm, Denmark

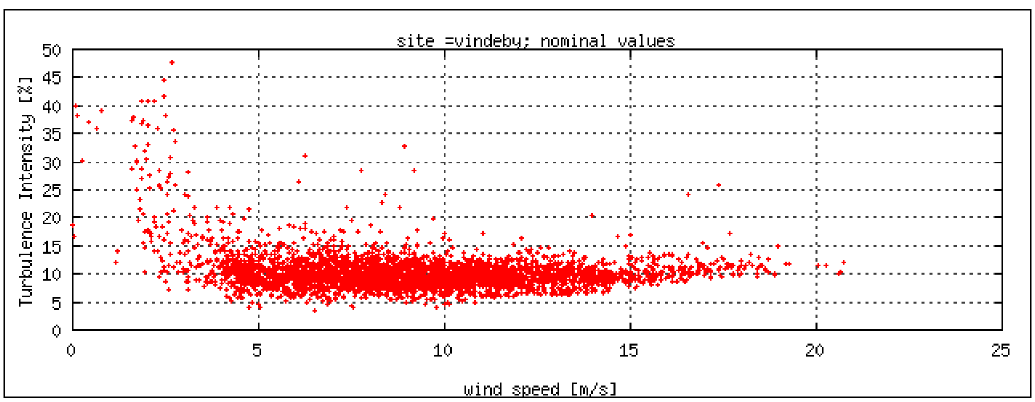
Site code **Vindeby**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	3	13
Number of channels with wind speed / wind direction	21	6
Number of sonics / height of met. Mast.	5	48 m
Hours of measurements / frequencies	2063	5 & 20 Hz

Project motivation
The primary goals of the Risoe Air Sea Experiment (acronym: RASEX) experiment were: 1) To carry out a "Kansas experiment over the sea"; that is, examine the validity of Monin Obukhov similarity theory over the sea using profiles and eddy correlation data. 2) To provide detailed information on off-shore wind climate characteristics of relevance for wind turbine design.

Measurement system
The world's first offshore wind farm is located on a shallow water area off the north-western coast of the island of Lolland, close to Vindeby in Denmark. The wind farm consists of 11 wind turbines positioned in two rows oriented approximately in a NW-SE direction. The wind turbines are Bonus 450 kW machines with a rotor diameter of 35 m and a hub height of 37 m above average sea level. The distance between the wind turbine rows are 300 m, and so is the distance between the turbines in each of the rows. The most southerly placed wind turbine is closest to the coast, and the distance is approximately 1.5 km. In order to investigate the offshore- and coastal wind climate three 45 m high meteorological towers were erected at the site. Two of these were located offshore and denoted by SMW (sea mast west) and SMS (sea mast south), respectively.

Acknowledgements
Rebecca Barthelmie, Risø National Laboratories and SEAS, Denmark.



Nominal turbulence vs. wind speed.

Site = Vallersund, Norway

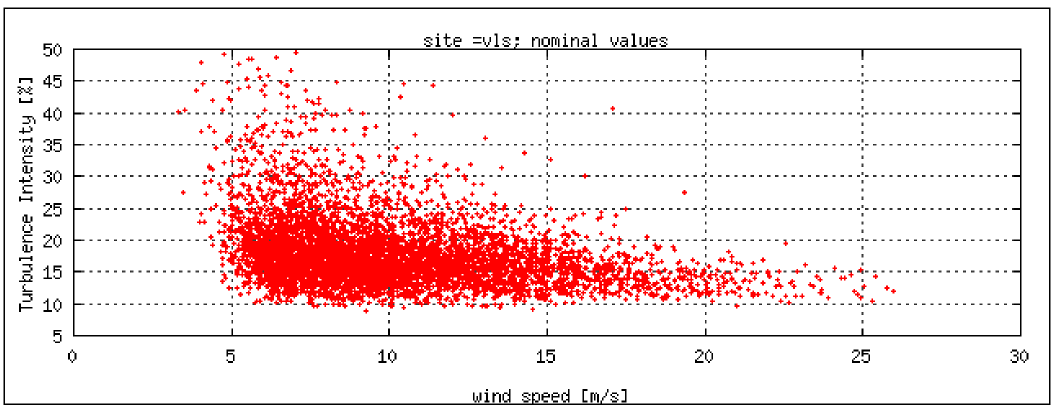
Site code **Vls**

Dominating terrain/ orography	Coastal	Hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	4	1
Number of sonics / height of met. Mast.	0	30 m
Hours of measurements / frequencies	3756	0.85 Hz

Project motivation
The project started in 1990, and the purpose was to study the wind structure, and to compare wind measurements to energy production from a neighbouring WECS.

Measurement system
The measurement station consists of 30 m mast with wind speed sensors at 30, 18, 10, and 5 m, and direction sensor at 12 m. Temperature has been measured at 30 and 10 m heights. The logging frequency has been 0.85 Hz.

Acknowledgements
Jørgen Løvseth, NTNU, Norway.



Nominal turbulence vs. wind speed.

Site = Windy Standard, Scotland

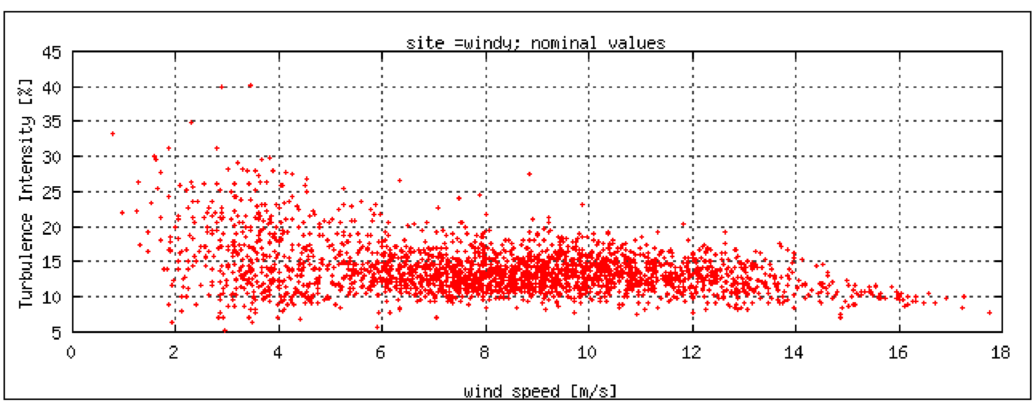
Site code **Windy**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	4	1
Number of sonics / height of met. Mast.	0	33 m
Hours of measurements / frequencies	405	10 Hz

Project motivation
The CEC has declared that a central objective of its R&D actions in the field of wind energy is to reduce the cost of wind generated electricity to 0.04 ECU/kWh or less. It is probable that this target will be first reached on sites which offer high energy density but which also bring considerable risks due to high extreme wind speeds, severe turbulence due to highly complex terrain, and conditions of icing. It is essential that these risks are properly studied and understood in order that the full potential of such hostile sites might be safely realised. Thorough investigations have been undertaken of the meteorology, the behaviour and loading of the wind turbines at Windy Standard in the U.K. also at Acqua Spruzza in Italy. The objectives of the project have been as follows: 1)to understand, and hence reduce, the risks associated with the use of wind farm sites in hostile conditions; 2)to provide a critical appraisal of present design procedures used for hostile environments, 3) to refine the design classification of wind turbines for such sites; and 4) to disseminate the results of the project to wind turbine manufacturers, wind farm developers, Classification Societies and Standards bodies.

Measurement system
Meteorological instruments were monitored at three heights: 7.5 m, 16.5 m and 33.5 m. Cup anemometers at 7.5 m, 16.5 m and 33.5 m were heated. There was also a sonic anemometer at 7.5 m. No icing of instruments was experienced during the period of data supplied to the Danish Technical University. The meteorological mast was upwind of the turbine at which loads and other operational parameters were measured. The meteorological mast consists of a single conical steel tower which therefore causes considerable wake effects downwind.

Acknowledgements
Mark Johnston, Garrad Hassan & Partners Ltd., United Kingdom.



Nominal turbulence vs. wind speed.

Site = Zeebrugge , Belgium

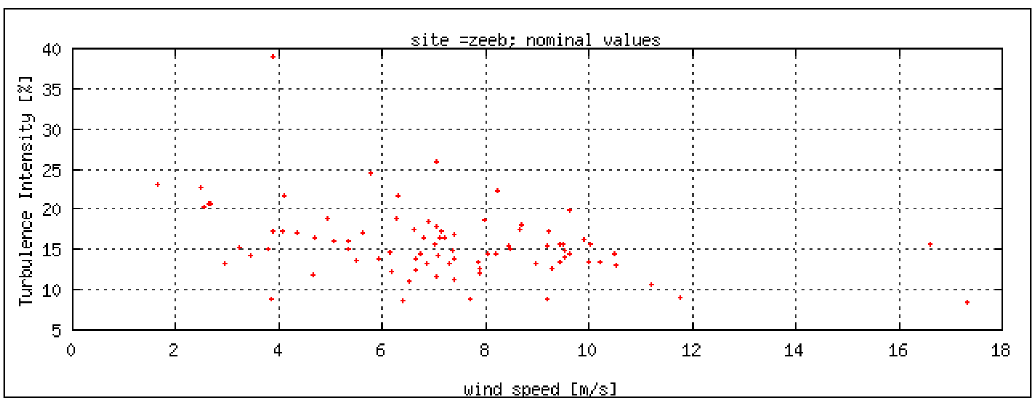
Site code **Zeeb**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	23
Number of channels with wind speed / wind direction	2	1
Number of sonics / height of met. Mast.	0	64 m
Hours of measurements / frequencies	103	2 Hz

Project motivation
On the sea-port of Zeebrugge in Belgium, 22 turbines are installed. 20 turbines of 200 kW (1986), 1x 175 kW, 1x 400 kW (1997) and 1x 600 kW (1998) turbine. The University of Brussels does measurements on the 600 kW turbine to examine the dynamic behaviour of the blades, nacelle, and mast.

Measurement system
The University of Brussels installed a 64 m wind-measuring mast. On top and on the intermediate height of 40 m, wind-speed is measured. Data is transferred to a central computer. The wind speeds on 40 m and 64 m together with the wind direction are interpreted with LabView . Data recording frequency is 2 Hz and the duration is 3600 sec.

Acknowledgements
Luc DeWilde, University of Brussels, dept. Fluid Dynamics, Belgium.



Nominal turbulence vs. wind speed.

4.2 Wind turbine structural response time series

Site = Sky River wind farm, Tehachapi, USA.

Site code **Skyv39**

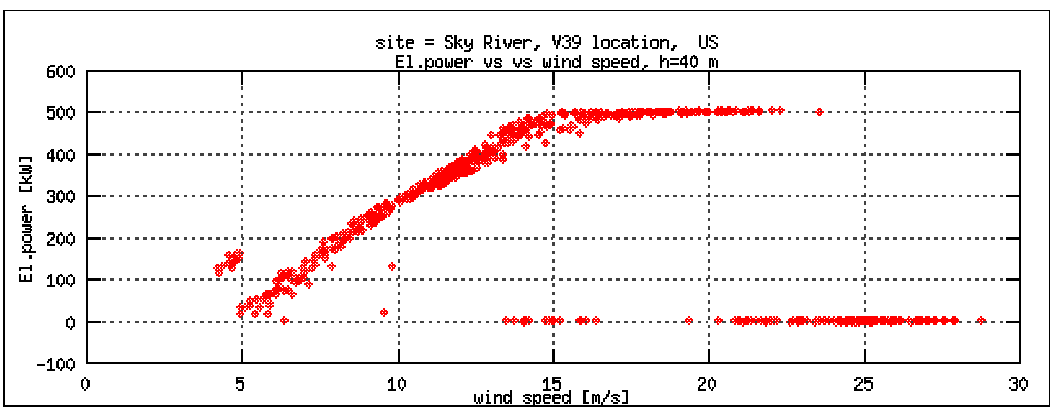
Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2	2
Number of instruments in WTGS	22	41 m
Hours of measurements / frequencies	105	32 Hz

Project motivation
Verification of the structural integrity of a wind turbine involves analysis of fatigue loading as well as ultimate loading. With the trend of persistently growing turbines, the ultimate loading seems to become relatively more important. For wind turbines designed according to the wind conditions prescribed in the IEC-61400 code, the ultimate load is often identified as the leading load parameter.

The objective of the Oak Creek project is to conduct a combined experimental and theoretical investigation of blade-, rotor- and tower loads caused by extreme wind load conditions occuring during normal operation as well as in stand still situations (where mean wind speeds exceeds the cut-out wind speed), with the purpose of establishing an improved description of the ultimate loading of three bladed pitch- and stall controlled wind turbines.

Measurement system
The main objective of the turbine specific measurements is to determine the dynamic loading of the wind turbine under different operating conditions in the wind farm in mountainous terrain.

Acknowledgements
Søren Markkilde Petersen, Risø National Laboratories, Denmark.



Nominal power vs. wind speed.

4.3 Wind resource data

Site = Alsvik, Gotland, Sweden

Site code **Alsvik**

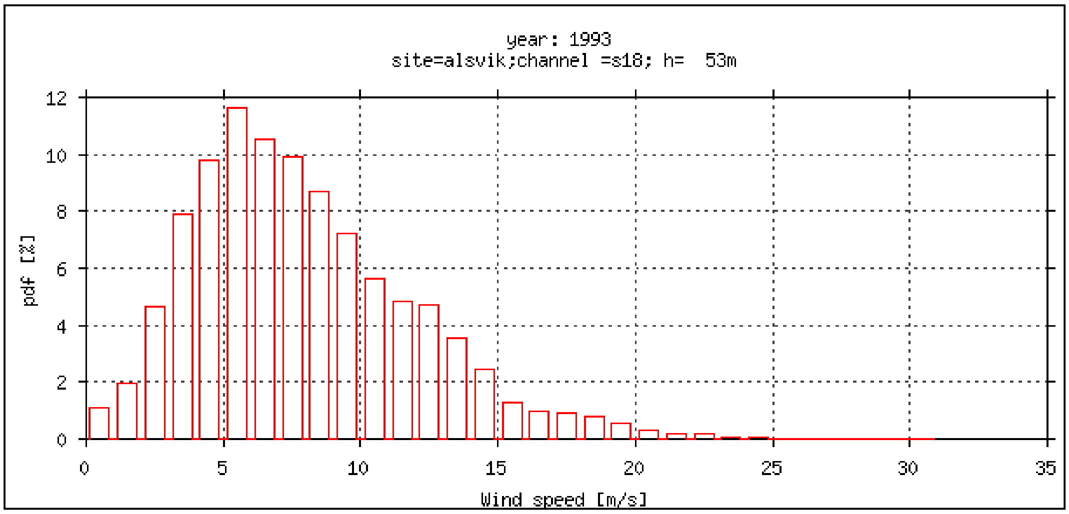
Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	2	4
Number of channels with wind speed / wind direction	6	2
Number of years / mast height	1991-1994	53 & 53 m
Hours of measurements / duration	17060	10 min.

Project motivation
Meteorological measurements from flat, coastal site on Gotland equipped with four wind turbines.

Measurement system
1 Hz data at eight levels on two 54 m towers during four years. 20 Hz data at three levels on one 54 m tower during one year.

Comment
These resource data is based on time series, which is stored as 10 minute averages including minimum, maximum, standard deviation and turbulence intensity.

Acknowledgements
Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Distribution of wind speeds, measured at Alsvik, Sweden, 1993.

Site = Cabauw, The Netherlands

Site code **Cabauw**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1 (h=10m)	1 (h=10m)
Number of years / mast height	1986-2000	213m
Hours of measurements / duration	123476	1 hour

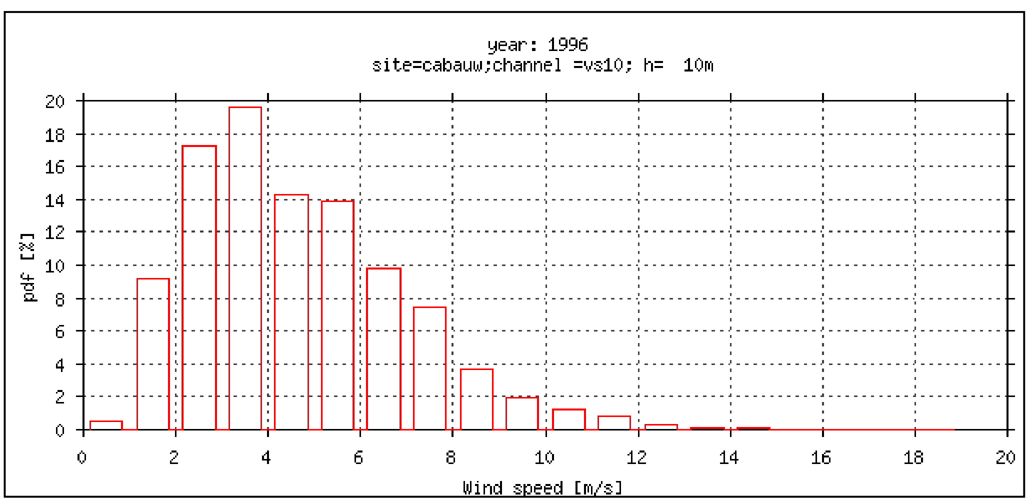
Project motivation
In the frame work of the project "a manual of design wind data for wind turbines ", measurements from the Royal Netherlands Meteological Institute (KNMI) were used extensively.

The KNMI allows the use of these data under the conditions: users of the data refer to the source of the data e.g. with the sentence: The Cabauw wind data were made available by the Royal Netherlands Meteological Institute (KNMI).

The KNMI appreciates to be informed how the data were treated. and likes to get relevant reports. In general commercial use of the data is not allowed. Information about the terms for commercial use can be obtained at the KNMI, attention to W.A.A. Monna, Section atmosferic research, P.O. Box 201, 3730 AE De Bilt, NL.
Resource data covering the period from 1/7 1986 to 31/12 1999 has been included.

Measurement system
The Cabauw meteo mast is a tubular tower with a height of 213 m and a diameter of 2 m. Guy wires are attached at four levels. Artificial wind speed and wind direction mean values (1 hour) with reference to 10 m agl. and based on propellor readings has been included as resource data.

Acknowledgements
Terry Hegberg, ECN and KNMI, The Netherlands.



Distribution of wind speeds, measured at Cabauw, NL 1996.

Site = Skipheya, Frøya, Norway

Site code **Ski**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	3	1
Number of channels with wind speed / wind direction	9	1
Number of years / mast height	1995	100
Hours of measurements / duration	6580	10 min.

Project motivation

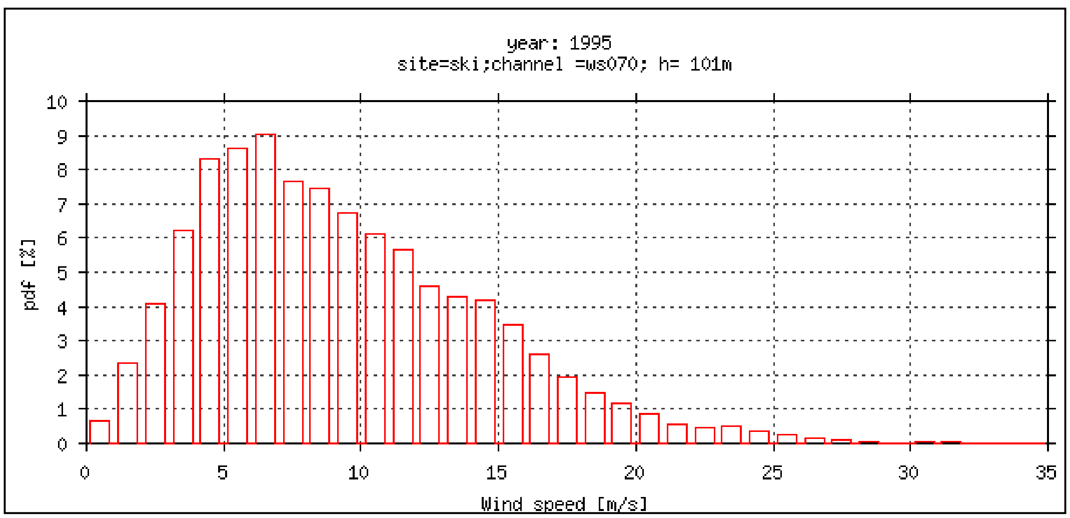
The station was build as a part of the Norwegian Wind Energy Programme in 1980. The purpose was to study the wind structure in details. Particularly, a database for high wind speed condition was desired. Data were originally intended for wind energy production; the dimension of the masts corresponds to a large WECS. The station should also serve as a reference station for other measurement stations in the region. Together with a fourth mast 4 km further west (Sletringen) the station has provided data for calculation of dynamic wind loads on off-shore constructions.

Measurement system

The measurement system consists of 3 meteorological masts (100, 100 and 45 m) placed in a triangle 80-180 metres apart. Ten-minute average of wind speed and direction have been recorded since 1982. From 1988, the logging frequency has been 0.85 Hz.

Acknowledgements

Jørgen Løvseth, NTNU, Norway



Distribution of wind speeds, measured at Skipheya, Norway, h=101m, 1995.

Site = Risø, Denmark

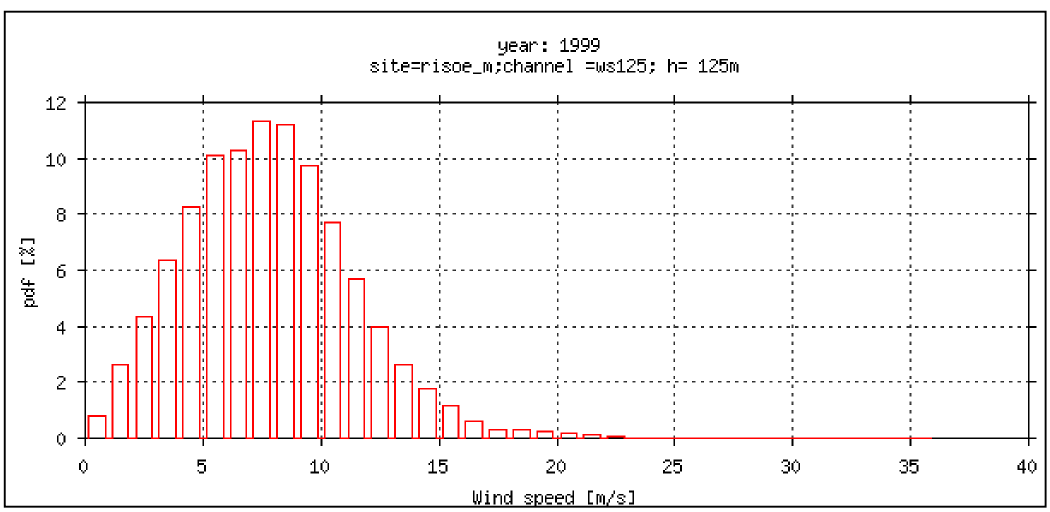
Site code **Risoe_m**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	2
Number of years / mast height	1996-2000	123 m
Hours of measurements / duration	43848	10 min.

Project motivation
The meteorologist of Risø have since the start of Risø in 1956 collected climatological data from measuring masts both within Denmark and outside the country. The data have mostly been collected to obtain relevant climate statistics for the locality in question.
Examples can be: Establishment of a climatology of atmospheric dispersion for a planned site for a power plant or an other production facility. Estimation of the the local windspeed distribution for evaluation of wind power resource or of the extreme wind load on structures and buildings.
Description of seasonal and long term exchange between the atmosphere and different types of vegetation. The data have also proven useful to in connection with events of various kinds, such as tracking storm surges across the country, estimating contaminated regions for transient events as different as nuclear and industrial accidents and air borne diseases.

Measurement system
Data from the Risø sites consist typically of atmospheric pressure and wind direction, wind speed in several heights, and temperature in at least two heights, such that climatology for wind speed and direction, wind variation with height and thermal stability can be established. At some stations also measurements of humidity, incoming solar radiation, and wind variability are obtained. Typically the measurements consist of ten minuttes averages recorded every ten minuttes. Details of the data are reported on the individual pages for each measuring station.

Acknowledgements
Gunner Jensen, Risø National Laboratories, Denmark



Distribution of wind speeds, measured at Risø, DK, h=125m, 1999.

Site = Tjæreborg, Denmark

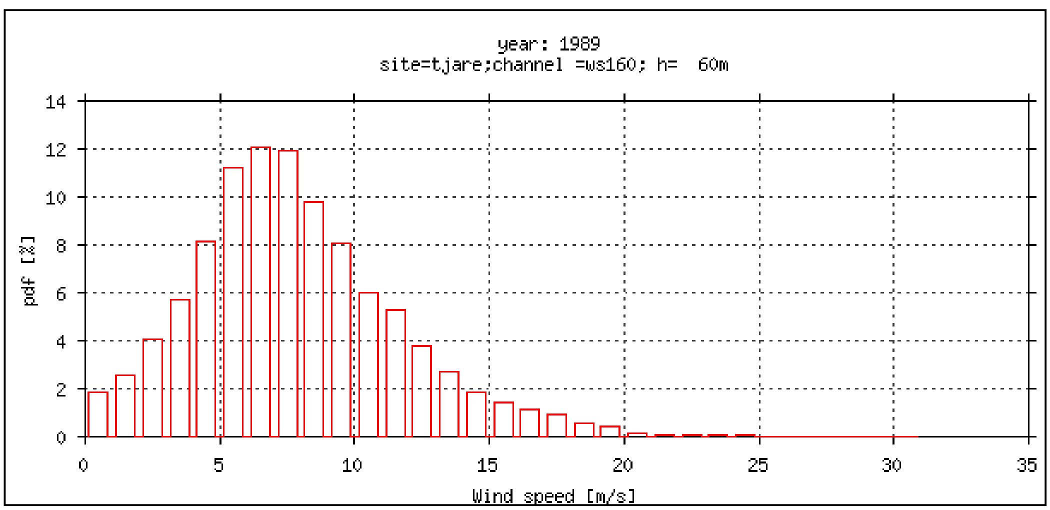
Site code **Tjare**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	8	4
Number of years / mast height	1988-1992	90 & 90 m
Hours of measurements / duration	33500	10 min.

Project motivation
The primary goal was to design and build a 2MW wind turbine at Tjæreborg, Esbjerg. This project was accomplished with an intensive measuring programme where both mechanical loads and the wind climate on the site was measured - and analysed. The wind data were recorded as part of this measurement programme.

Measurement system
The measurement system consists of 2 meteorological mast, mast no.1 was placed in front and mast no.2 behind the wind turbine - referring to the dominant wind sector. The measurements system was based on two HP-data loggers and the data was transferred to a central computer (HP operating HP-Basic with home developed data handling routines and programs). The system operation was primarily focusing on recording structural loads included a number of meteorological channels.

Acknowledgements
Peter Christiansen, Tech-wise A/S (former Elsamprojekt), Denmark



Distribution of wind speed measured at Tjæreborg, DK, 1989.

Site = Vindeby offshore farm, Denmark

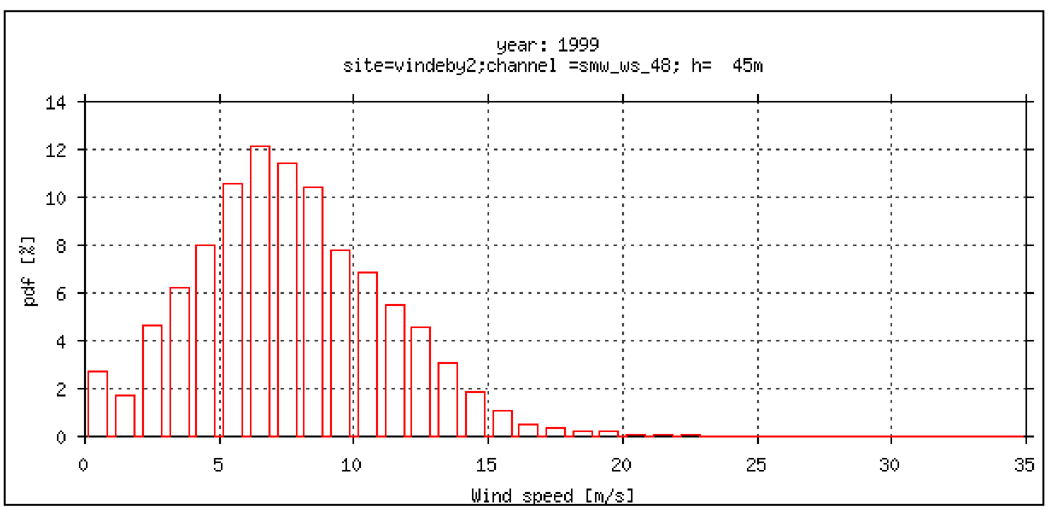
Site code **Vindeby**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	3	13
Number of channels with wind speed / wind direction	9	3
Number of years / mast height	1993-2000	45, 48 & 48 m
Hours of measurements / duration	47400	30 min.

Project motivation
Investigate long term off-shore climate and validate WasP prediction program.

Measurement system
The world's first offshore wind farm is located on a shallow water area off the north-western coast of the island of Lolland, close to Vindeby in Denmark. The wind farm consists of 11 wind turbines positioned in two rows oriented approximately in a NW-SE direction. The wind turbines are Bonus 450 kW machines with a rotor diameter of 35 m and a hub height of 37 m above average sea level. The distance between the wind turbine rows is 300 m, and so is the distance between the turbines in each of the rows. The most southerly placed wind turbine is closest to the coast, and the distance is approximately 1.5 km. In order to investigate the offshore- and coastal wind climate three 45 m high meteorological towers were erected at the site. Two of these were located offshore, denoted by SMW (sea mast west) and SMS (sea mast south), respectively.

Acknowledgements
Rebecca Barthelmie, Risø National Laboratories & SEAS, Denmark



Distribution of wind speeds, measured at Vindeby, DK, 1999.

5. Acknowledgements

The Ministry of Environment and Energy, Danish Energy Agency, The Government of Japan, The Netherlands Agency for Energy and the Environment (NOVEM), The Norwegian Water Resources and Energy Administration (NVE), The Swedish National Energy Administration (STEM), The Government of the United States of America and the IEA R&D Wind Agreement are all acknowledged for the support that have made the completion of this work possible.

6. References

[1] Hansen, K.S. and Courtney, M.S. (1999). Database on wind Characteristics. ET-AFM-9901, Department of Energy Engineering, DTU, Denmark.

[2] Larsen, G.C. and Hansen, K.S. (2001). Database on Wind Characteristics - Philosophy and Structure. Risø-R-1299.

[3] Larsen, G.C. and Hansen, K.S. (2001). Database on Wind Characteristics - Users Manual. Risø-R-1300.

Appendix A: Site documentation for Bockstigen

For each site represented in the database a "Description of Measurement Setup" - file is prepared and made available on the web-server as a PDF document. This appendix is a copy of the PDF file prepared for the measurements recorded at the Swedish Bockstigen site.

Preparing notes

The document contains background information for the measured data stored in The Database of Wind Characteristics. This PDF document is prepared by Kurt S. Hansen, Department of Mechanical Engineering, DTU, Denmark and is based on information from external sources (Ingemar Carlén Teknikgruppen AB). It contains a copy of the project information, the site information and the master sensor list.

Content

A.1 Introduction

Motivation

The Bockstigen off-shore wind farm consists of five 500 kW wind turbines erected three km of the SW coast of the island of Gotland on the Baltic. The project was launched in order to gain experience from bottom mounted offshore wind turbine installation. Specifcally, the method of drilling a hole for a monopile foundation, directly into the limestone rock, was in focus for the investigations.

Measurement system

Measurements are performed in one meteorological mast, and on one instrumented turbine (no measurements in the rotating system). Data are sampled by use of several loggers (DataScan 20 Hz), and the signals are transfered through an optical fibre cable (4500 m) to an onshore cabin. Data is continiously stored on video8 tapes.

A.2 Site Description

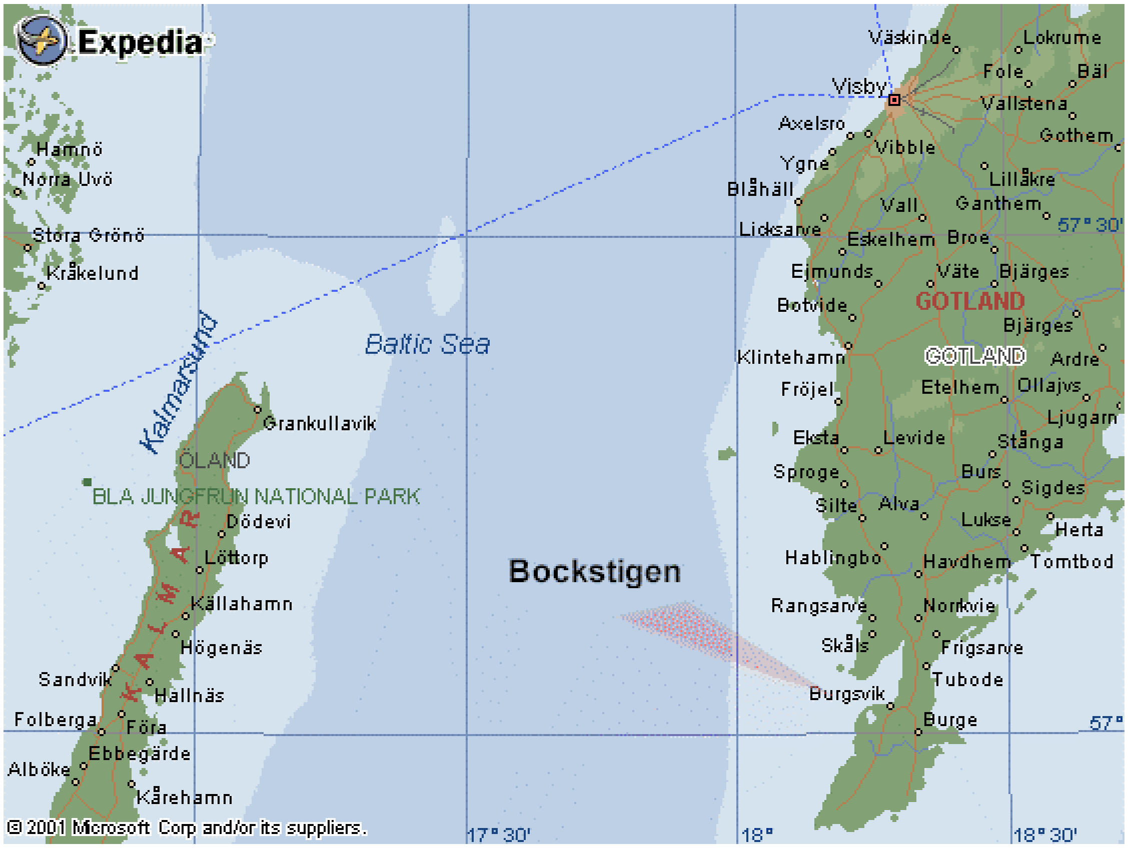


Figure A2-1: Location of the measuring site, the Bockstigen off-shore wind farm.

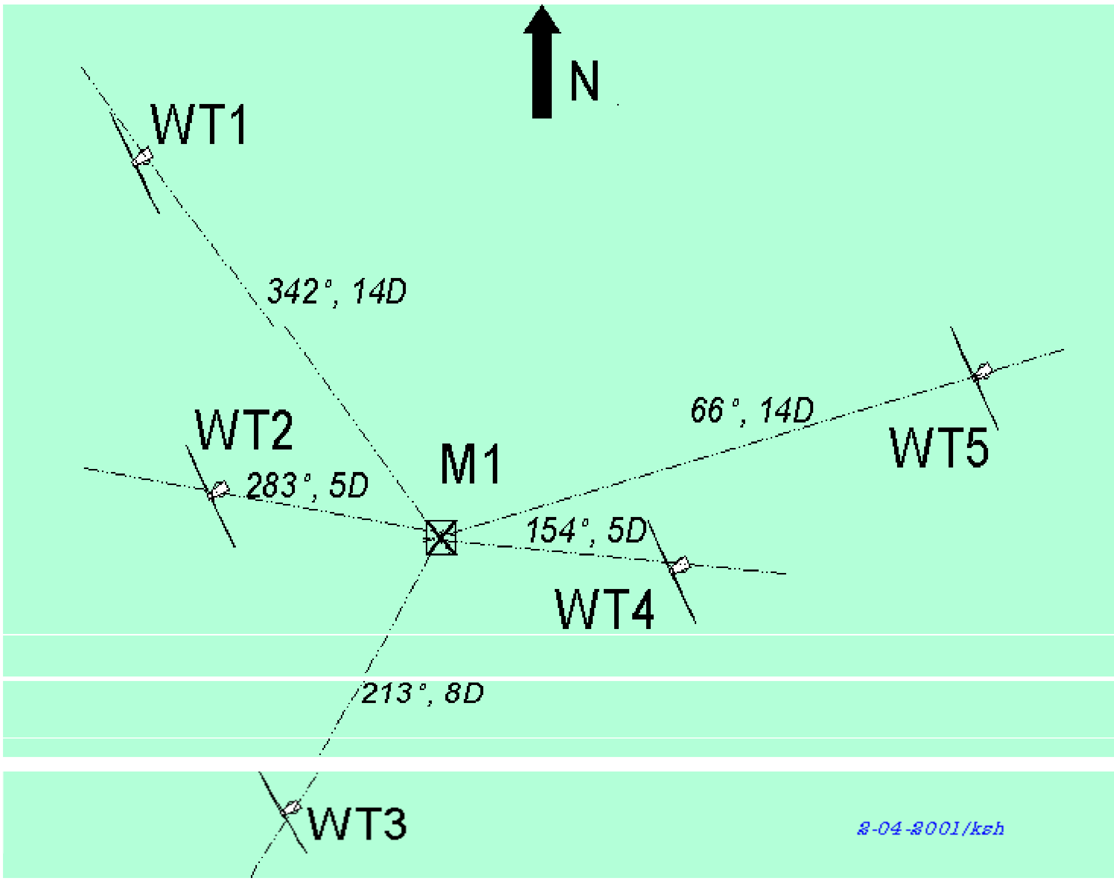


Figure A2-2: Measuring site-plan used in the Bockstigen wind farm.

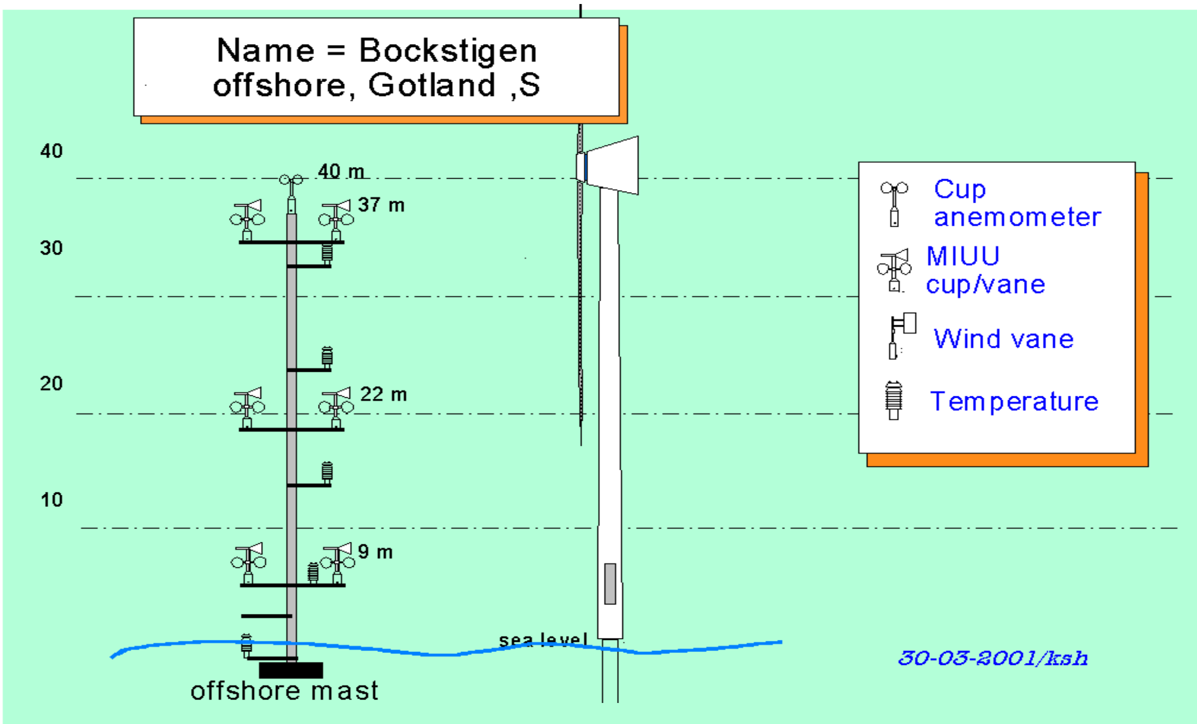


Figure A2-3: Site layout for Bockstigen measurements, 1 mast and 5 wind turbines.

A.3 Available Channels

The available channels are listed in table A3-1.

Table A3-1: Available channels from the Bockstigen measurements

Mast number	Name	height	Signal type	Instrument
1	D8s	8.4	D	CUPVANE
1	S8s	8.4	S	CUPVANE
1	D8n	9.0	D	CUPVANE
1	S8n	9.0	S	CUPVANE
1	D22n	22.4	D	CUPVANE
1	S22n	22.4	S	CUPVANE
1	D22s	22.9	D	CUPVANE
1	S22s	22.9	S	CUPVANE
1	S37s	36.8	S	CUPVANE
1	D37s	36.8	D	CUPVANE
1	D37n	37.2	S	CUPVANE

1	S37n	37.2	D	CUPVANE
1	S40	40.0	S	CUP
1	Tabs0	0.0	Tabs	Thermometer
1	Tabs6	6.0	Tabs	Thermometer
1	Tabs15	15.0	Tabs	Thermometer
1	Tabs25	25.0	Tabs	Thermometer
1	Tabs35	35.0	Tabs	Thermometer
1	Rhum6	6.1	Rhum	

A.4 Available Measurements

This Section contains a summary of the available measurements in the database.

Table A4-1: Summary of measurements

Terrain	Offshore
Orography	Flat
Number of masts	1
height[s]	40 m
wind speed measurements at 5 heights	8, 22, 37 & 40 m
wind direction measurements at 3 heights	8, 22 & 37
Frequency	1 Hz
hours of measurements	1239
number of runs	1239

At the nominal plots, each dot represents 3600 seconds.

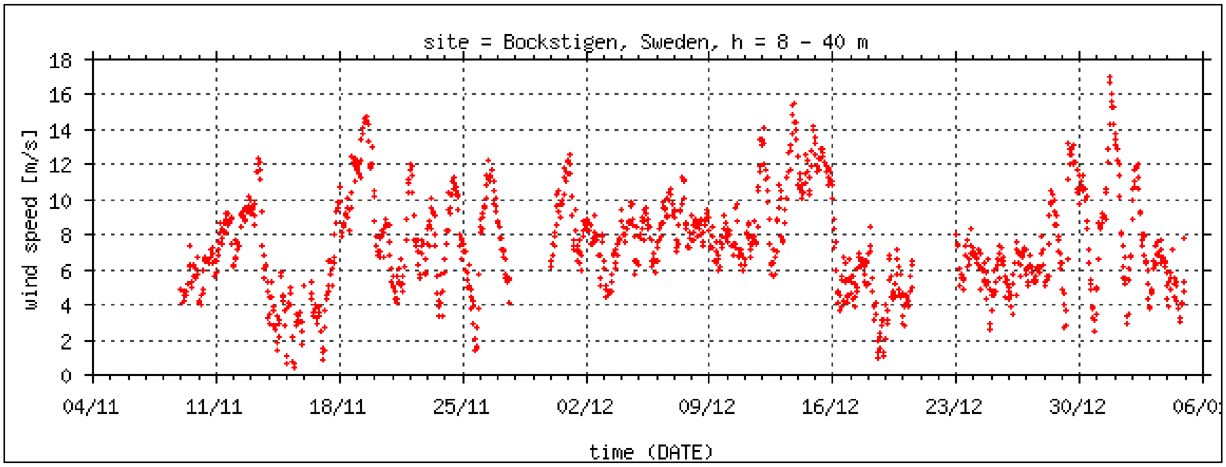


Figure A4-1: The nominal wind speed (average wind speed based on 7 cups; the reference period is 60 minutes).

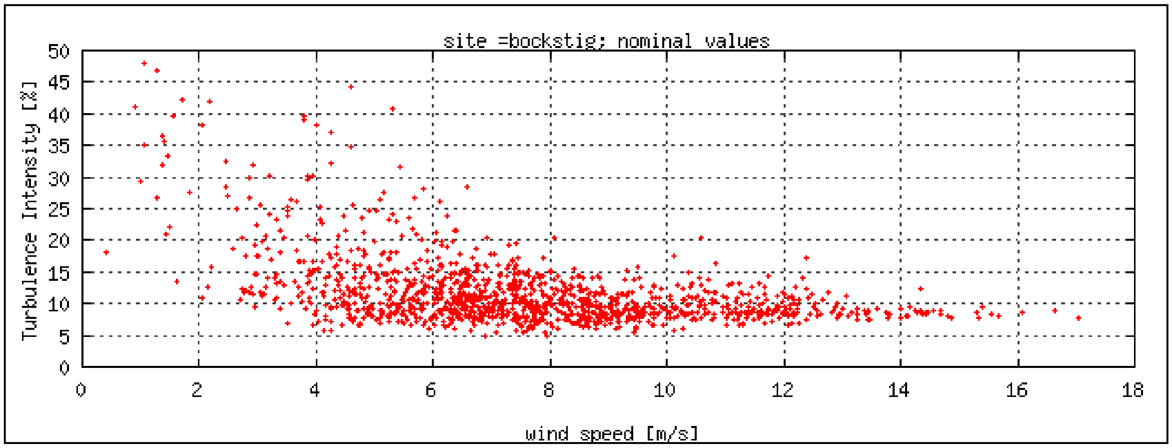


Figure A4-2: The nominal turbulence intensity (average turbulence intensity based on 7 cups; the reference period is 60 minutes).

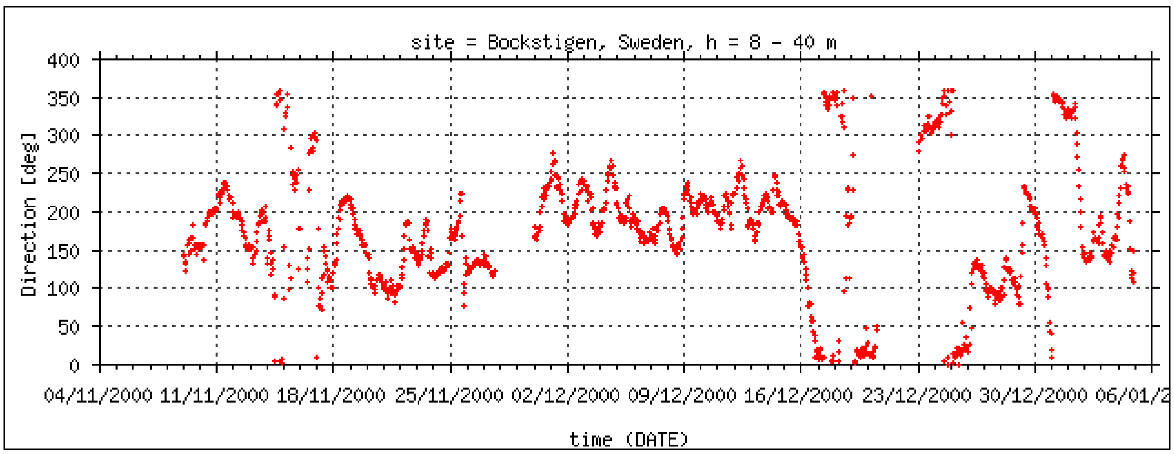


Figure A4-3: The nominal direction (based on 1-3 vanes; the reference period is 60 minutes).

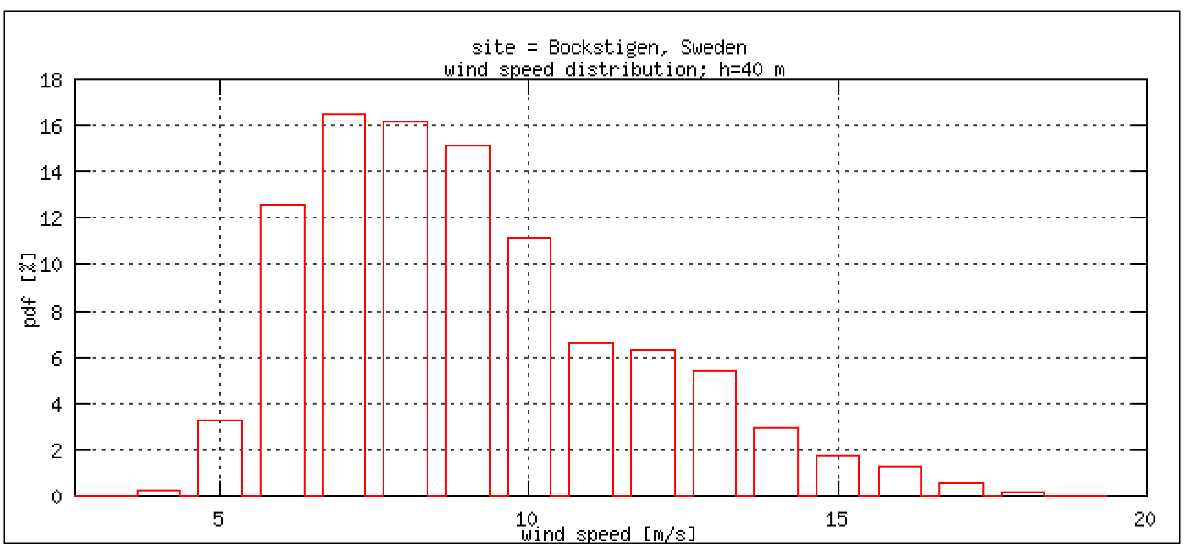


Figure A4-4: The wind speed distribution for all periods; h=40 m.

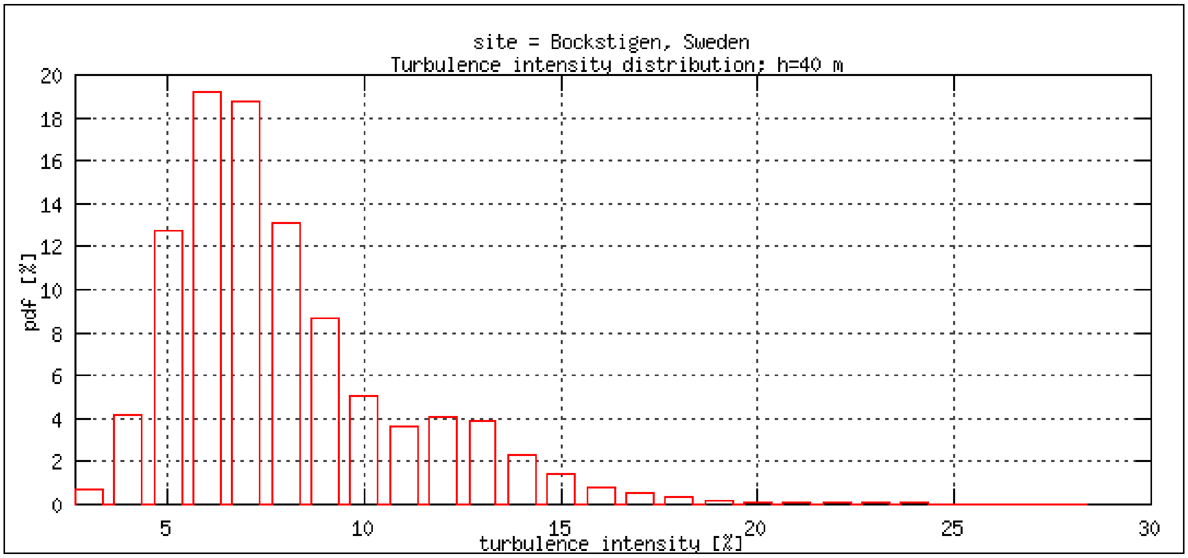


Figure A4-5: The distribution of the turbulence intensity for all periods; h=40 m.

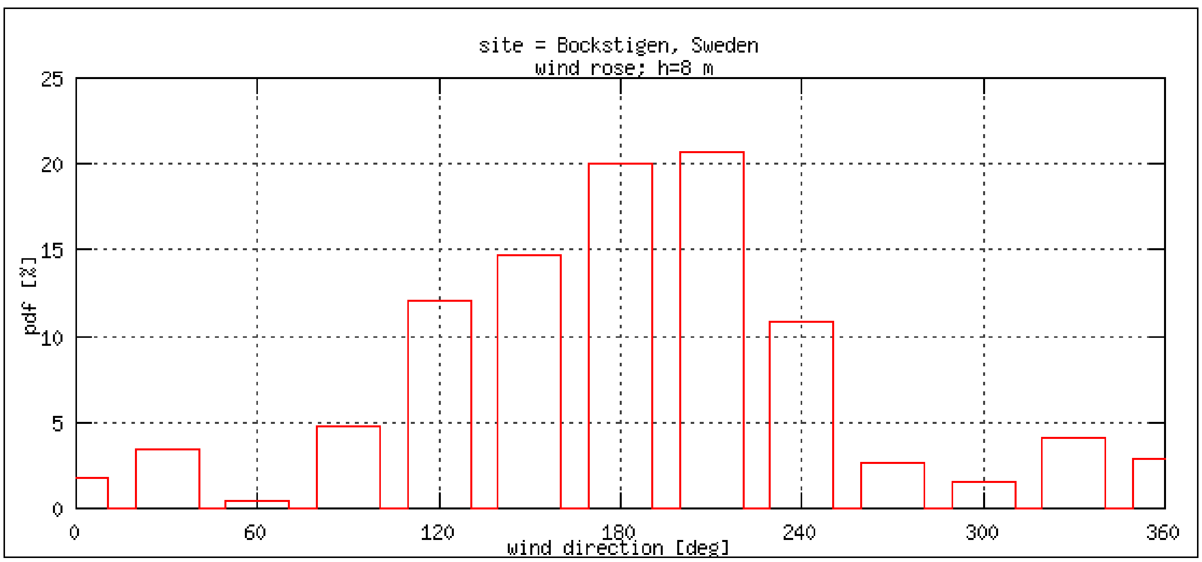


Figure A4-6: The wind rose; h=8 m.

A.5 References

1. Poppen M., Dahlberg J-Å., Thor S-E, ”Proposal to a Programme for Evaluation of the Wind Turbine Units”, FFAP-V-046, FFA, Stockholm (in Swedish).
2. Ronsten G. et. al. , ”Instrumentation and initial evaluation of the 2.5 MW Bockstigen offshore wind farm”, EWEC 99, Nice, March 1999.
3. Ronsten G. et. al. ,”Evaluation of Loads, Power Quality, Grid Interaction, Meteorological Conditions and Power Performance of the first Swedish Wind Farm at Bockstigen”, OWEMS, Syracuse, Italy, April, 2000

A.6 Project Information

```
;=======================================================
;  Project information
;  ===================
;  Project = Bockstigen offshore windfarm, Gotland, Sweden
;  Prepared by Ingemar Carlén, Teknikgruppen AB, Sweden
;  version : 28-3-2001
;  Modf.   : 29-3-2001 /ksh
;=======================================================
[Basic_information]
project_code      = bockstigen
Institution       = FFA (FOI / Flygteknik)
Person            = Goran Ronsten
e_mail            = rng@foi.se
URL               = www.foi.se
Address           = S-172 90 Stockholm
Telephone         = +46 8 55503000
Telefax           =
Collaborators     = MIUU , Teknikgruppen AB
Funding_agencies  = NUTEK , STEM
project_start_date= Spring 1997 (met mast installed autumn 1999)
project_end_date  =

[Project Motivation]
The project was launched in order to gain experience from bottom mounted
offshore wind turbine installation. Specifcally, the method of drilling a
hole for a monopile foundation, directly into the limestone rock, was in
focus for the investigations.

[Measurement_System]
Measurements are performed in one meteorological mast, and on one
instrumented turbine (no measurements in the rotating system). Data are
sampled by use of several loggers (DataScan 20 Hz), and the signals are
transfered through an optical fibre  cable (4500 m) to an onshore cabin.
Data is continiously stored on video8 tapes.

[Attachments]
Number_of_publications  = 3
Number_of_maps          = 2
Number_of_graphs        = 2

[publication_1]
Description             = Report
Reference               = Poppen M., Dahlberg J-Å., Thor S-E, ”Proposal to a
Programme for Evaluation of the Wind Turbine Units”, FFAP-V-046, FFA,
Stockholm (in Swedish).

[publication_2]
Description = Conference paper
Reference   = Ronsten G. et. al. , ”Instrumentation and initial evaluation
of the 2.5 MW Bockstigen offshore wind farm”, EWEC 99, Nice, March 1999

[publication_3]
Description = Conference paper
Reference   = Ronsten G. et. al. ,”Evaluation of Loads, Power Quality, Grid
Interaction, Meteorological Conditions and Power Performance of the first
Swedish Wind Farm at Bockstigen”, OWEMS, Syracuse,Italy, April, 2000

[Map_1]
Description = Location of the wind farm, southwest of the island of Gotland.
Filename    = draw_01.pdf

[Map_2]
Description = Orientation of meteorological mast, and wind turbines.
Filename    = draw_02.pdf
```

```
[Graph_1]
Description = Temperature profiles in Land Tower, Coastal Tower,and sea
tower (see Map_1).
Filename    = graph_01.pdf

[Graph_2]
Description = Frequency of Richardson number (Sea Tower and Coastal Tower).
Filename    = graph_02.pdf
```

A.7 Site Information

```
;========================================================
;  Site information; site_code = Bockstig
;  ======================================
;  Project = Bockstigen offshore windfarm, Gotland, Sweden
;
;  Prepared by Ingemar Carlén, Teknikgruppen AB, Sweden
;  version :  1-3-2001
;  Modf.   : 29-3-2001 /ksh
;========================================================
[Site_global_data]
site_name              = Bockstigen, Gotland, Sweden
version                = 01-03-21
site_code              = bockstig
parent_project         = bockstigen
longitude              =  18  8’ 46.50”
latitude               =  57  2’  9.25”
altitude               = 0.0
country                      = Sweden
dominant_terrain_type        = offshore
dominant_orography           = flat
no_of_measurements_location   = 1
no_of_wind_turbines          = 5
[mast_1]
x     = 0.0
y     = 0.0
z     = 0.0
roughness_class   = 1,1,1,1,1,1,1,1,1,1,1,1
turbine_wakes     = f,f,t,t,f,f,t,t,f,t,t,t
desription        =  40  m  lattrice  mast  located  4500  m  off-shore  from  the
island of Gotland.
[turbine_1]
x           = 490.7
y           = 159.5
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=
[turbine_2]
x           = 171.5
y           = -39.6
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=
[turbine_3]
x           =-153.6
y           =-236.5
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=
```

```
[turbine_4]
x           =-178.0
y           =  86.8
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=
[turbine_5]
x           =-215.2
y           = 483.3
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=

[Attachments]
no_of_site_maps =
no_of_site_drawings=
no_of_site_photos  = 1
no_of_site_graphs  =
no_of_mast_photos  = 1
no_of_mast_drawings=

[site_photo_1]
description    = The Bockstigen wind farm in strong winds (seen from the
air).
Filename       = photo_01.jpg

[mast_photo_1]
description    = Meteorological mast seen from sea surface.
Filename       = photo_02.jpg
```

A.8 Master Sensor List

```
;========================================================
;  Master sensor list
;  site_code = Bockstig
;  ====================
;
;  Prepared by Ingemar Carlén, Teknikgruppen AB, Sweden
;  version : 21-3-2001
;  Modf.   : 29-3-2001 /ksh
;========================================================
Master Sensor File]
Site_code            = bockstig
Version              = 21-03-01
No_of_sensors        = 13

[sensor_1]
Sensor_name          = cv8s
Sensor_type          = CUVA
Sensor_height        = 8.4
Boom_direction       = 195
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          = 7.0 m
Boom_shape           = circular , telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
Mast_dimension       = 2.0 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
```

```
Last_calib.          =
No_of_signals        = 2

[Signal_1]
Signal_name          = s8s
Signal_type          = S
Time/Length Constant = 1 s
MinMeasVal           = 0.45
MaxMeasVal           = 43.0
Units                = m/s
Accuracy             =

[Signal_2]
Signal_name          = d8s
Signal_type          = D
Time/Length Constant = 1 s
MinMeasVal           =  0
MaxMeasVal           =  360
Units                = deg
Accuracy             =

[sensor_2]
Sensor_name          = cv8d
Sensor_type          = CUVA
Sensor_height        = 9.0
Boom_direction       = 15
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          = 7.0 m
Boom_shape           = circular , telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
Mast_dimension       = 2.0 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
Last_calib.          =
No_of_signals        = 2

[Signal_1]
Signal_name          = s8n
Signal_type          = S
Time/Length Constant = 1 s
MinMeasVal           = 0.45
MaxMeasVal           = 43.0
Units                = m/s
Accuracy             =

[Signal_2]
Signal_name          = d8n
Signal_type          = D
Time/Length Constant = 1 s
MinMeasVal           =  0
MaxMeasVal           =  360
Units                = deg
Accuracy             =

[sensor_3]
Sensor_name          = cv22s
Sensor_type          = CUVA
Sensor_height        = 22.9
Boom_direction       = 195
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          = 5.25 m
Boom_shape           = circular , telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
```

```
Mast_dimension       = 1.45 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
Last_calib.          =
No_of_signals        = 2

[Signal_1]
Signal_name          = s22s
Signal_type          = S
Time/Length Constant = 1 s
MinMeasVal           = 0.45
MaxMeasVal           = 43.0
Units                = m/s
Accuracy             =

[Signal_2]
Signal_name          = d22s
Signal_type          = D
Time/Length Constant = 1 s
MinMeasVal           =  0
MaxMeasVal           =  360
Units                = deg
Accuracy             =

[sensor_4]
Sensor_name          = cv22n
Sensor_type          = CUVA
Sensor_height        = 22.4
Boom_direction       = 15
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          = 5.25 m
Boom_shape           = circular , telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
Mast_dimension       = 1.45 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
Last_calib.          =
No_of_signals        = 2

[Signal_1]
Signal_name          = s22n
Signal_type          = S
Time/Length Constant = 1 s
MinMeasVal           = 0.45
MaxMeasVal           = 43.0
Units                = m/s
Accuracy             =

[Signal_2]
Signal_name          = d22n
Signal_type          = D
Time/Length Constant = 1 s
MinMeasVal           =  0
MaxMeasVal           =  360
Units                = deg
Accuracy             =

[sensor_5]
Sensor_name          = cv37s
Sensor_type          = CUVA
Sensor_height        = 36.8
Boom_direction       = 195
Sensor_direction     =
```

```
Top_mounted          = F
Mast_number          = 1
Boom_length          = 3.5 m
Boom_shape           = circular , telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
Mast_dimension       = 1.05 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
Last_calib.          =
No_of_signals        = 2

[Signal_1]
Signal_name          = s37s
Signal_type          = S
Time/Length Constant = 1 s
MinMeasVal           = 0.45
MaxMeasVal           = 43.0
Units                = m/s
Accuracy             =

[Signal_2]
Signal_name          = d37s
Signal_type          = D
Time/Length Constant = 1 s
MinMeasVal           =  0
MaxMeasVal           =  360
Units                = deg
Accuracy             =

[sensor_6]
Sensor_name          = cv37n
Sensor_type          = CUVA
Sensor_height        = 37.2
Boom_direction       = 15
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          = 3.5 m
Boom_shape           = circular , telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
Mast_dimension       = 1.05 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
Last_calib.          =
No_of_signals        = 2

[Signal_1]
Signal_name          = s37n
Signal_type          = S
Time/Length Constant = 1 s
MinMeasVal           = 0.45
MaxMeasVal           = 43.0
Units                = m/s
Accuracy             =

[Signal_2]
Signal_name          = d37n
Signal_type          = D
Time/Length Constant = 1 s
MinMeasVal           =  0
MaxMeasVal           =  360
Units                = deg
Accuracy             =
```

```
[sensor_7]
Sensor_name          = c40
Sensor_type          = CUP
Sensor_height        = 40.0
Boom_direction       =
Sensor_direction     =
Top_mounted          = T
Mast_number          = 1
Boom_length          =
Boom_shape           =
Boom_dimension       =
Mast_dimension       = vertical top , 38 mm
Meas_distance        =
Serial_no            = T 39519
Manufacturer         = Vaisala
Model_spec.          = 151
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = s40
Signal_type          = S
Time/Length Constant = 2.0 m
MinMeasVal           = 0.4
MaxMeasVal           = 75.0
Units                = m/s
Accuracy             =

[sensor_8]
Sensor_name          = tabs0
Sensor_type          = Term
Sensor_height        = 0.0 (sea surface)
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          =
Boom_shape           =
Boom_dimension       =
Mast_dimension       =
Meas_distance        =
Serial_no            =
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs0
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
Accuracy             =

[sensor_9]
Sensor_name          = tabs6
Sensor_type          = Term
Sensor_height        = 6.1
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          =
Boom_shape           =
Boom_dimension       =
Mast_dimension       =
Meas_distance        =
```

```
Serial_no            =
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs6
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
Accuracy             =

[sensor_10]
Sensor_name          = tabs15
Sensor_type          = Term
Sensor_height        = 15.0
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          =
Boom_shape           =
Boom_dimension       =
Mast_dimension       =
Meas_distance        =
Serial_no            =
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs15
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
Accuracy             =

[sensor_11]
Sensor_name          = tabs25
Sensor_type          = Term
Sensor_height        = 25.0
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          =
Boom_shape           =
Boom_dimension       =
Mast_dimension       =
Meas_distance        =
Serial_no            =
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs25
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
```

```
Accuracy             =

[sensor_12]
Sensor_name          = tabs0
Sensor_type          = Term
Sensor_height        = 35.0
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs35
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
Accuracy             =

[sensor_13]
Sensor_name          = rhum
Sensor_type          = HUM
Sensor_height        = 6.1
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Mast_dimension       =
Serial_no            = 1
Manufacturer         = unknown
Model_spec.          = u1
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = rhum6
Signal_type          = RHUM
Time/Length Constant =
MinMeasVal           =  0
MaxMeasVal           = 100
Units                = %
Accuracy             =
```

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Pages	Tables	Illustrations	References
75	53	57	3

Abstract (max. 2000 characters)

The main objective of IEA R&D Wind Annex XVII - Database on Wind Characteristics - is to provide wind energy planners and designers, as well as the international wind engineering community in general, with easy access to quality controlled measured wind field time series observed in a wide range of environments. The project partners are Sweden, Norway, U.S.A., The Netherlands, Japan and Denmark, with Denmark as the Operating Agent.

The reporting of IEA R&D Annex XVII falls in three separate parts. Part one deals with the overall structure and philosophy behind the database, part two accounts in details for the available data in the established database bank and part three is the Users Manual describing the various ways to access and analyse the data.

The present report constitutes the second part of the Annex XVII reporting. Basically, the database bank contains three categories of data, i.e. *i*) high sampled wind field time series; *ii*) high sampled wind turbine structural response time series; and *iii*) wind resource data. The main emphasis, however, is on category *i*). The available data, within each of the three categories, are described in details. The description embraces site characteristics, terrain type, measurement setup and the amount of available data.

Descriptors INIS/EDB

DATABASE; EXTREME WIND; RESOURCE DATA; TURBULENCE; WIND; WIND ANALYSIS; WIND DIRECTION GUSTS; WIND FIELD DATA; WIND LOADING; WIND SHEAR GUSTS; WIND SPEED GUSTS; TIME SERIES; WIND STATISTICS; WIND TURBINE; WIND TURBINE LOADING.

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