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Database on Wind Characteristics

Structure and Philosophy

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November 2001

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 first part of the Annex XVII reporting, and it contains a detailed description of the database structure, the data quality control procedures, the selected indexing of the data and the hardware system.

IEA R&D Wind Annex XVII
Database on Wind Characteristics

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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 Reference [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 of 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 first part of the Annex XVII reporting and contains a description of the database structure, the data quality control procedures, and the hardware system.

Basically, “Database on Wind Characteristics” contains three types of data - high sampled wind field time series, high sampled wind turbine structural response time series related to selected wind field time series, and wind resource data. A variety of wind climates and terrain types are represented with significant amounts of time series. Data have been chosen selectively with a deliberate over-representation of high wind and complex terrain cases. This makes the database ideal for wind turbine design needs. Diversity has also been an important aim and this is realised with data from different terrain types ranging from offshore to mountain.

In order to establish a suitable search system we have constructed a database for the detailed registration of field measurements, ranging in scope from the administrative level down to the mounting details of individual sensors. Emphasis has been given to ensure a high level of documentation of the measurement set-up included in the database, and the implemented data are quality checked according to a number of different criteria such as presence of spikes, noise, level jumps and trends. Subsequently the data are indexed using a variety of parameters, including conventional statistics and extremes, turbulence intensity, gusts and wind shear.

The search and data selection system is based on the performed indexing and has been developed to fully utilise the interactive nature of the World Wide Web. After quality control and indexing, the actual wind data are copied in a standard format to a fast hard disc (with a capacity of 40 GB) on the database server. The server is accessible via ftp, and allows direct downloading of data files from a WEB browser.

The present report is structured as follows: Chapter 3 provides an overview of the database system including descriptions of the hardware system, the WEB interface and handling of the input. Chapter 4 deals with the detailed organisation and verification of the database content - i.e. formats, file structure, data handling, screening procedures and data indexing. Finally, Chapter 5 describes the SQL database - the “heart” of the entire system.

3. Overview of the database system

The database is implemented as a world wide web (www) system. In this way any user with an Internet connection and a WEB browser, regardless of computer or operating system type, can obtain access to:

- All raw data;
- Signal quality, indexed values and statistics;
- Background documentation;
- Interactive, online queries;
- Interactive, immediate downloading of interesting time series;
- Online graphical view of time series;
- Online graphical view of results;
- Online graphical view of resource data distributions.

Due to the fast development in internet-tools, much consideration was given to ensure an advanced, yet stable, platform for development and maintenance of the database. By the time both the development software and the developers abilities have matured, the technology has moved on. Now the database operator must use significant resources in keeping the old technology running with a constant stream of new and not always compatible browser versions.

3.1 Server organisation

The objective of Annex XVII is to organise raw, measured time series data and resource data together with appropriate background documentation. Organising the data includes, among other aspects, the process of establishing an easy access to specific signals – in other words establishing a useful index database for the data content.

From the user side, the database system is organised in three elements: the web server[1], the database server and the FTP-server as illustrated in Figure 3.1-1. These three servers can be physically present on a single machine. At present the database server and the web server reside on one computer, whereas the FTP server reside on a separate machine. The function of the three servers are described below:

1. *FTP server* gives access to the raw time series and raw resource data, which are stored on a fast 40 GB hard disc.

2. *Web server* is used as a gateway and provides browser access to the ftp server, input definition documents, background documentation and issue queries to the database server by use of SQL[2] protocol.

3. *Database server* contains large tables with project, site and instrumentation specific information. The database server contains the basic statistics for all time series as well as indexed values based on a reference period of 10 minutes and resource data.

[1] Server is used in the terms of giving access to the hosted data or documents.
[2] Standard Query Language used for database queries.

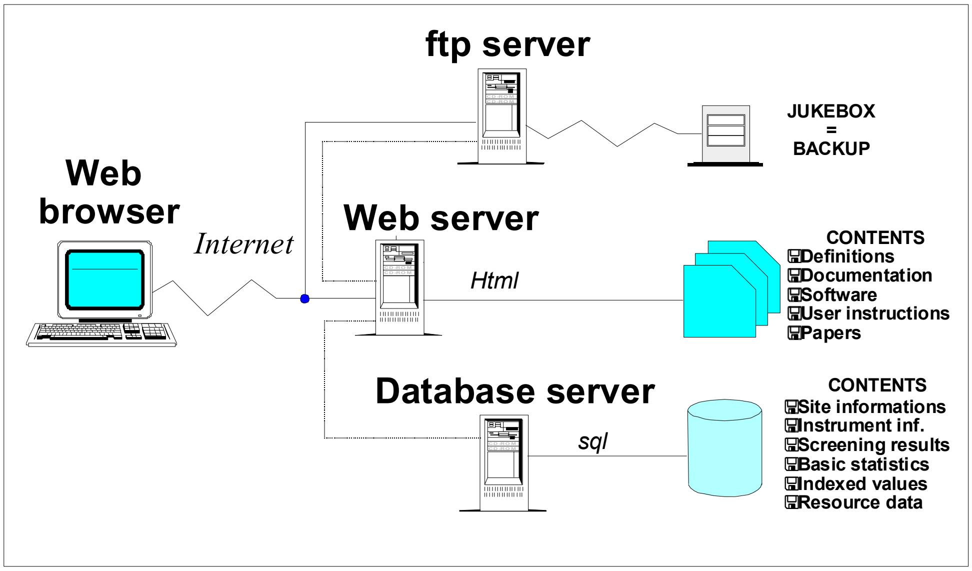

Figure 3.1-1: Server structure.

In addition to the commonly used hardware system, an independent hardware backup system exists. The major differences between this system and the conventional system are that the computers hosting the servers are slower, and that the fast hard disc storage facility is replaced by a slower "jukebox" based system. Physically, the time series data reside on CD-ROMs loaded in a so-called "jukebox". This is a storage system composed of 4 CD-ROM drives, racks for 150 CD-ROMs and a robot system for automatic loading and changing of CD-ROMs. With the help of control software, running on an NT server, access to the data on the CD-ROMs is completely transparent, appearing as part of the local file system for local users. To maintain a high system availability a copy of each hard disc are stored in a safe, and these disc can easily be installed in a new server and be operational within a few hours.

3.2 Input data handling

The data handling process for entering *time series* data into the database consists of several steps as illustrated in Figure 3.2-1. All the actions reflect the internal database structure, which was defined before the criteria for data handling could be settled.

The preliminary step is to identify the potential raw data suitable for the database. The selected data are thus subsequently converted from "local" format to a common (database) file format. In addition documentation of the measuring site and instrumentation setup are prepared in a common descriptive format. Possessing knowledge of the original data format as well as of the details concerning the measurement setup, this work is usually performed by the *data provider*. When complete, the data files and documentation are forwarded to the *Database.*

The second step consists of data format checking and registration. The site_code is created, and all the documentation is included in the database. The data are checked for correct file structure and format and are corrected where necessary. Afterwards the data are copied to the fast hard disc and made publicly accessible through the FTP server. Finally, each time series is registered in the database, including information on time, location and basic statistics.

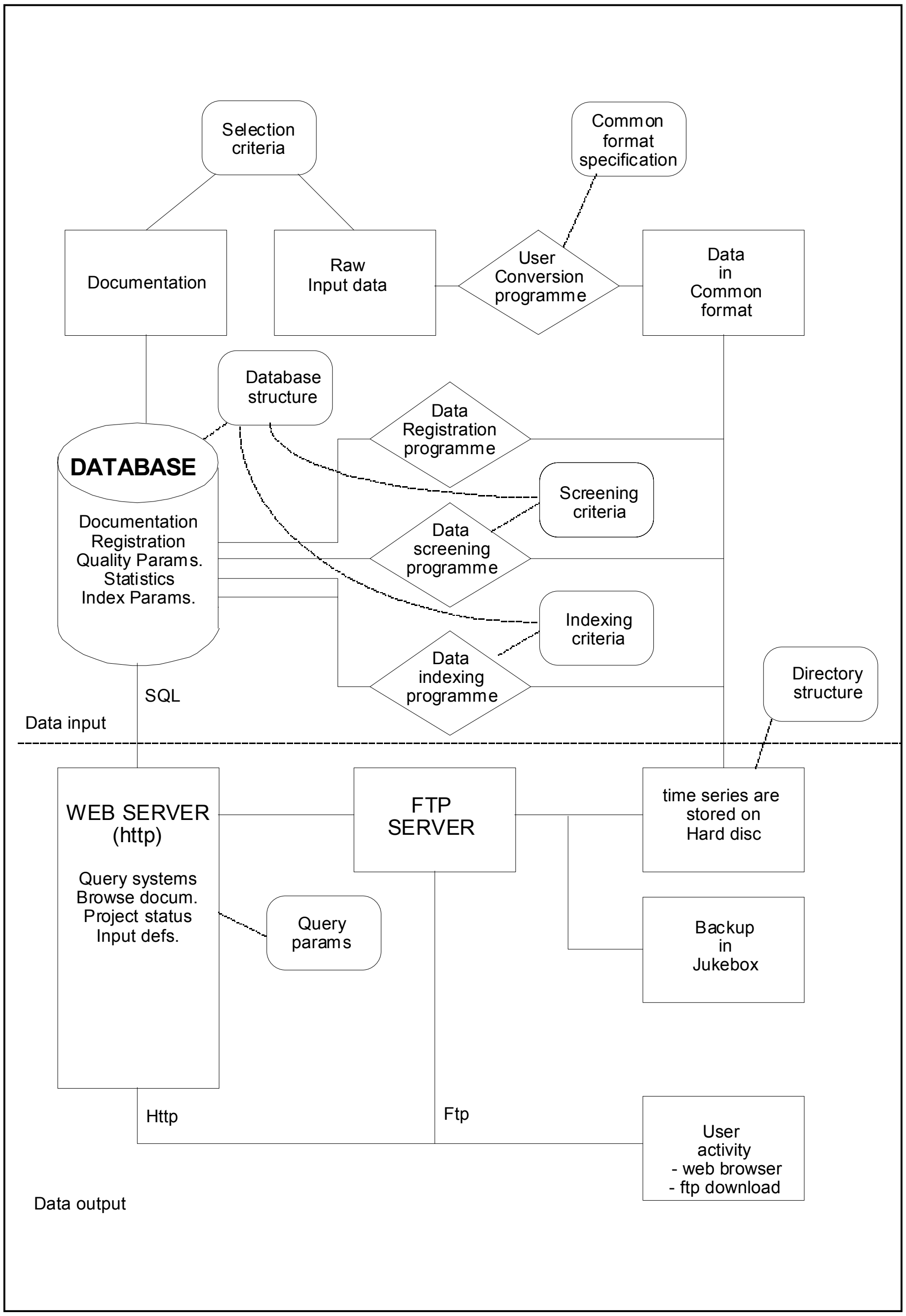

Figure 3.2-1 The data handling process.

The third step consists of a data quality screening according to some predefined screening criteria prepared in accordance with the database structure. The results from this quality screening are included in the database (and can be accessed through the site-channel query form - cf. Reference [2]). Afterwards, the time series are indexed at a 10-minute reference period level according to indexing criteria, defined in accordance with the internal database structure. The results of the indexing process are finally included in the database. Both the data screening and indexing process are performed with a dedicated client/server software package developed explicitly for this purpose.

The procedure for the *resource* data is somewhat simpler. These data are usually forwarded in raw ASCII files by the *data provided* and subsequently entered directly into the database together with relevant site documentation[3] after creation of the appropriate site_code.

3.3 Backup strategy

All *time series* data and *resource* data are stored on CD-ROMs, which reside in the JukeBox as shown on Figure 3.2-1. Furthermore, copies of all data are stored on a fast, huge (40GB) hard disc connected directly to the FTP-server. This configuration enables a fast access to the time series when creating online plots. The *database* is backed up on a regular basis when new data have been entered and the backup is stored on CD-ROMs.

3.4 The WEB interface

User access to the database server is established through *a web browser* (e.g. Netscape Communicator or Internet Explorer) at the address http://www.winddata.com. Through a browser the user can inspect or download background information, definitions and documentation. Most importantly, the user has access to the search system, which allows identification of time series having the properties of interest. Searching is performed by filling out the desired parameters in pre-defined query forms (cf. Reference [2]). The connection between the query forms and the database server is based on SQL and is invisible for the user.

Access to the data included in the database is established using a selection of four different query types:

1. *Simple queries* enables quick and simple access and are based on *nominal*[4] values and *basic statistics*[5]. Here, the idea is to reduce the volume of statistics as much as possible by representing the time series by one mean wind speed (the mean of all the wind speed sensors), one direction (the mean of all the direction sensors) and one turbulence intensity (the mean turbulence intensity from all the wind speed sensors) only. Obviously, only a general impression of the time series remains but suffices to satisfy perhaps 80% of user queries. Being relatively compact, searching in this database is fast and straightforward. The results are presented either in tables, in plots or as a list of files referring directly to raw time series located at the fast hard disc.
2. *Advanced queries* are based on 10-minute statistics and indexed values. The statistics and the indexed values can be used in a large number of combinations. Here, the statistics contain values for each channel for each ten minutes of the run (in contrast to basic (=nominal) statistics which contain only one speed, one direction and one turbulence intensity per run). Due to the level of detail, searching in these data is slower than for a

[3] In analogy with the *time series* data, the site documentation for the *resource* data includes descriptions of the measuring site as well as of the instrumentation setup (prepared in the same descriptive format as used for the time series data).

[4] Each run is characterised with only nominal speed, one nominal direction and one nominal turbulence intensity. The exact definition of the *nominals* is given in Reference [1].

[5] Basic statistics represent reference time periods varying between 600 and 3600 seconds.

simple query. The output from the advanced queries consists of a list of 10-minute periods fulfilling the specific query parameters. Furthermore, the results contain links to time series located at the fast hard disc.

3. *Site-channel queries* are based on basic statistics[5] and indexed values (e.g. turbulence intensity). Only one channel can be selected in each query. The output is a number of derived values (e.g. mean, standard deviation, min, max, range, stationarity factor, turbulence intensity, trend corrected turbulence intensity, skewness and kurtosis). Furthermore, the results contain links to time series located at the fast hard disc. It is a robust query applicable for detailed signal analysis.
4. *Resource data queries* are used to extract mean values[6] of wind speed, wind direction or other available channels for a specified period of time. It is a comparatively slow facility, while all data has to be extracted directly from the database and subsequently stored in data files. Afterwards the resulting data files can easily be downloaded to the client computer. In addition to the search facilities, each site description contains a facility to create online PDF plots of the available channels.

4. Implementation of data

Having given a brief overview of the input data handling in Section 3.2, the present Chapter contains a detailed description of the data selection criteria and the process of entering data into the database.

4.1 Data selection

The objective of Annex XVII is to create a database containing large amounts of wind data representing a wide range of relevant terrain types, instrumentation and operational wind turbine conditions. Special attention has been paid to identify data from types of sites and wind climates that was not already well represented in the database. Data of particular interest have, among others, included time series originating from offshore (and coastal) sites, time series from sites outside Europe, time series representing high spatial and/or temporal resolution and time series representing high wind sites.

The minimum requirements for acceptable data, satisfying the criteria stated above, include:

- At least one wind speed measurement;
- At least one wind direction measurement;
- Suitable temporal resolution of time series data (1 – 25 Hz);
- At least 50 hours of measurements for time series data;
- At least 1 year of measurements for resource data;
- Site or terrain type should be wind energy or wind engineering relevant;
- Well documented site and instrumentation.

Many experiments fulfil these criteria. To further narrow the choice it is necessary to consider the use of the database.

[6] The resource data represents reference time periods varying between 600 to 3600 seconds.

Desirable features in discriminating amongst time series include:

- Rare extreme events (storms);
- Sonic anemometer measurements (3D turbulence);
- Long periods of uninterrupted data;
- Rare terrain types;
- Measurements from wind farms including wake conditions;
- Climatological parameters (temperature, radiation, pressure, rain) available;
- Long term wind climatology available in addition to time series data.

4.2 Standard format

There are (at least) as many different data formats as there are experimenters. Therefore a standard format has been defined both for the background information and for the wind field data themselves.

4.2.1 Background information

In order to facilitate description of the background information for subsequent inclusion in the database, a number of reporting templates have been defined. These templates (empty forms) reflect the underlying database structure and comprise 3 parts:

1. *Project description file.*

This description contains information about the project, institutions and the contact address for people working with the project together with list of references related to the project. A detailed description of the input format is listed in Appendix A. Projects usually "own" one site, but for an experiment carried out at a regional or national level (for example a regional resource survey) it might be appropriate to define one governing project and a number of "child" sites.

2. *Site description file.*

This file documents descriptive features of the site: the location, terrain type, type of orography, the mast (or masts) and any nearby wind turbines. Drawings, photos, maps and WAsP description files may be included in the description. A detailed definition of the format is given in Appendix B. As indicated, there may well be several masts at one site. When the mast separation (spacing) approaches several kilometres, it may be more appropriate to define separate sites. A guiding rule here could be whether there would be any reasoning in using the data from the separated masts together in the same analysis.

3. *Master sensor list.*

The master sensor list defines all the instruments and channels entered in the database together with mounting information. Here it is important to distinguish between *models*, *instruments* and *signals*.

An *instrument* is a physical sensor, defined by its *model* type and serial number. All its salient physical features (e.g. dimensions and weight) are defined in the *model* type. The serial number specifies the precise physical manifestation of the given *model* type. Unique *instrument* characteristics are for example purchase date, service and calibration records.

A given *model* has one or more output *signals*, the discrete physical properties measured by the model. For example a cup anemometer has one *signal* (wind speed) whilst a sonic anemometer has four *signals* (3D wind velocity vector and virtual temperature).

The internal database structure further defines *mountings*, a complete definition of where an instrument is mounted, and *channels*, a given *signal* from a given *instrument* at a given *mounting*. For the sake of simplicity, the master sensor list merges *signal* and *mounting* definitions together, so that in practice a *signal* definition defines a *channel* in the database. A detailed definition of the master sensor list format is given in Appendix C.

4.2.2 Time series files

A simple flexible ASCII-file format has been selected mainly because it can be adapted to all the commonly used platforms (UNIX, MS-DOS, MS-Win95, MS-WinNT, Apple/Mac). This format is rather space consuming, but since the data are always stored in compressed form (using *pkzip*), this is not considered to be a problem. File compression and decompression software are readily available on all platforms.

A further choice concerns how to handle multiple channels and multiple sample frequencies (f. ex. often occuring when wind speeds are recorded both by cup anemometers sensors and by sonic sensors). Whilst data handling is simplified with only one channel per file, for many sites this would result in a large number of files per run. One file only containing all channels with possible differing frequencies would be unwieldy both for input and output. One file per discrete sample frequency results in few files per run (1 or 2) and has a simple internal file format. This was the solution adopted. The file name is derived from the date, time and sample frequency as follows:

tttt_fff.dat

where

tttt is the start time (hours and minutes)
fff is the sampling frequency in tenths of Hz.

The common file format consists of a *header* with general information and basic statistics, followed by the *scaled data* (one row per scans / one column per channel). A definition of the subheader contents are given below and in detail in Appendix D. The last part named [Additional Statistics] is optional:

[Common File Header]
1. Unique site code
2. Date and time of recording
3. Name of project information file
4. Name of site information file
5. Name of master sensor file
6. Sequence number
7. Available frequencies covering this period

8. Name of files covering the same period
9. Duration
10. Sensor configuration number
11. Runname based on recording time
12. Site name, which could be equal to site code

[File Header]
13. Name and location data file (file structure) with extension “dat”.
14. Number of scans
15. Number of sensors
16. Frequency of the current file

[Sensor Statistics]
17. Channel type, quality, height, wake, name, mean, st.dev., min, max, unit

[Additional Statistics]
18. Channel type, quality, height, wake, name, mean, st.dev., min, max, unit

[Data field]

The major fields are described in detail below:

[Common File Header] contains basic information referring to the site and is repeated in all the files (i.e. related to other sample frequencies) associated to this run.

[File Header] defines the size of the current data file, unique to this particular sample frequency.

[Sensor Statistics] contains the basic statistics for each of the channels present - one row per sensor. From left to right, the fields are:

sensor type (s = speed, d = direction etc.)
quality index (1 = good, -1 = bad)
sensor height
wind turbine wake (0 = no wake in signal, 1 = wake in signal)
sensor name
mean
standard deviation
minimum
maximum
units

[Additional Statistics] is optional and contains statistics for channels, which are not present in the data file as time series. The additional statistics section is used to include other relevant information, which are available such as e.g. climatology and wind turbine power outputs. The fields are defined as for the [sensor statistics], described above.

[Data Field] section contains all the scaled data - one scan per row - meaning that all channels listed in the same row are recorded at the same time. All data are stored in physical units [m/s], [deg] or [degC]. For time series delivered for inclusion, sonic data should be stored as raw, unaligned time series. Data alignment is performed at *DTU,* ensuring a uniform alignment procedure, and the aligned data (together with the raw, unaligned data) are included in the public version of the time series.

To conserve space, the data files do not contain any time signal. This time signal has to be derived based on starting time and the frequency, i.e. $t_i = t_{start} + (i-1)/frequency$ [sec]. An example of the data format is shown in Figure 4.2-1 and further details are given in Appendix D.

```
[Common File Header]
site_code       = andros
date            = 13- 8-94
time            = 10:53: 0
project_file    = andros.pro
site_file       = andros.sit
sensor_file     = andros.m01
sequence        = 2/12
frequencies     = 1
file_names      = 1053_010.dat
duration        = 600.00
sensor_cfg      = 1
run_name        = 199408131053
site_name       = andros
[File Header]
data_file       = \andros\1994\day225\1053_010.dat
frequency       = 1.0
no_of_scans     = 600
no_of_sensors   = 8
[sensor statistics]
s 1 18.0 0 s18e 9.73 1.01  6.5 12.4  [m/s]
s 1 31.5 0 s31e 10.17 1.01  6.8 14.0 [m/s]
s 1 40.0 0 s40e 9.96 0.96  7.5 12.2  [m/s]
s 1 18.0 0 s18n 8.06 0.93  5.9 11.0  [m/s]
s 1 31.5 0 s31n 9.44 1.01  6.9 13.7  [m/s]
s 1 40.0 0 s40n 9.67 1.01  7.0 12.6  [m/s]
d 1 18.0 0 d18e 356.0  6.9  337  381 [deg]
d 1 31.5 0 d31e 338.4  6.7  322  361 [deg]
[Additional Statistics]
powa 1 31.5 0 v27-225 118.5  21.7  69.1 182.5 [kw]
[data field]
10.0 11.4 11.8 7.7 8.8  9.3   1.4 338.4
10.5 10.4 11.4 7.3 9.3  9.9 358.6 344.2
 9.9 10.3 11.3 7.6 9.7 10.0 359.8 338.6
...
```

Figure 4.2-1 Illustration of the data format.

4.2.3 Resource data files

There is not any defined standard input format for the resource data. The data has to be stored in an ASCII-file with a column for time stamp and a column for each channel values (e.g. mean, standard deviation, min and max). Each value must be comma separated.

4.3 File directory structure

In order to keep track of the vast amount of time series, a systematic directory structure has been defined. The directory structure is based on three key parameters: site_code, year and day of recording. Identification of the time series is determined by the four primary digits of the file name, as described in section 4.2.2 and illustrated in Figure 4.3-1.

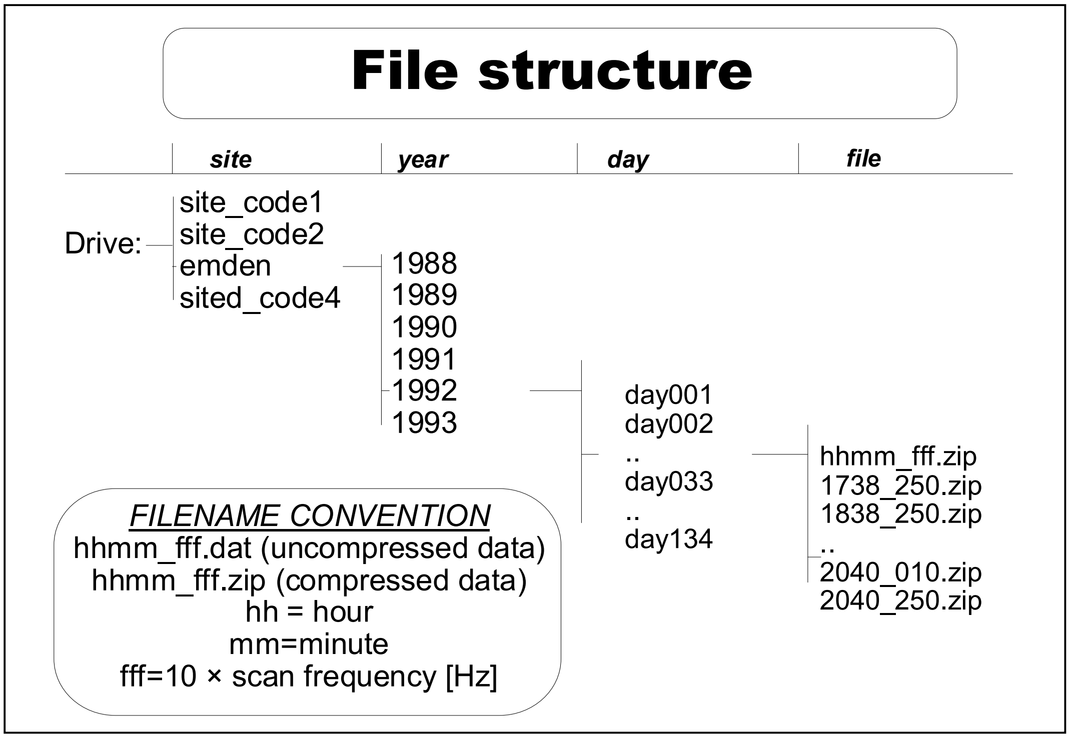

Figure 4.3-1 File directory structure.

4.4 Data handling

The post processing of received data are performed according to the flow chart shown in Figure 4.4-1.

The following steps are performed as part of the data arrival procedure:

1. All received material is checked for attached virus according the current state of the antivirus software package;
2. All time series are checked for correct zip-file integrity which involve a checksum control of the compressed file;

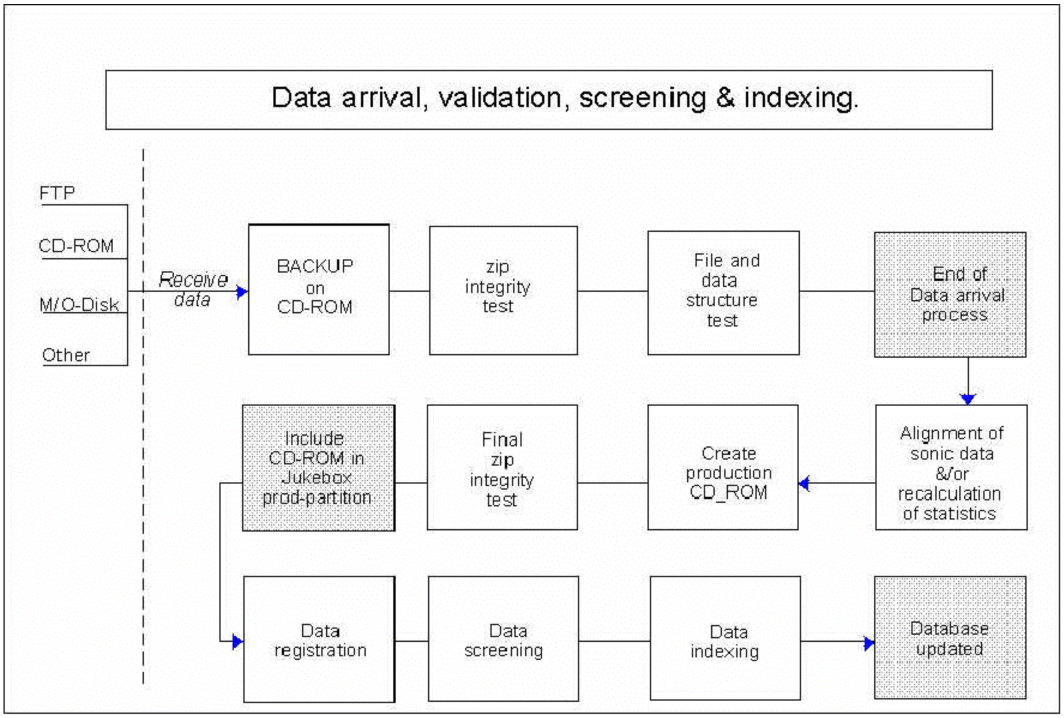

Figure 4.4-1 Data handling.

3. All the time series are checked for correct directory structure according to the definition given in Section 4.3. The directory structure is rearranged if the structure does not agree with time and date information from the [Common File Header];
4. All time series are checked for correct internal file structure as listed in Section 4.2. The file format is fixed in case of errors or deviations before further use;
5. Sensor statistics (stored in the file header) are checked by recalculating the statistics from the time series data. A rudimental quality control is applied with two possible sanctions: i) adjustment of the data quality parameter in the [sensor statistics] header to indicate reduced signal quality, or ii) amputation of channels with severe problems;
6. Sonic anemometer data are aligned and co-variances calculated as described below. The aligned data are added to the time series files and the co-variances are added as additional statistics;
7. The time series are stored on a new CD-ROM with consecutive numbers [prod_001, prod_002,..];
8. The new CD-ROM is tested for integrity (checksum);
9. The content of the new CD-ROM is copied to the fast hard disc on the database server, whereby these data are made publicly accessible. Subsequently, the new CD-ROM is mounted in the jukebox;
10. Details of the time series and the sensor run statistics are entered in the database.

4.4.1 Sonic anemometer signal co-ordinate transformations

The signals from sonic anemometers consists of 3 unaligned wind speed components (x,y,z) referring to an orthogonal co-ordinate system. A fourth signal, temperature (derived from the instantaneous speed of sound) is usually also available.

The standard Risø alignment procedure for sonic signals is used. This process transforms the unaligned (x,y,z) co-ordinate system to a second orthogonal system (u,v,w) where the u vector points in the direction of the mean flow, and hence the mean speeds in the v and w directions are zero. Since there are many different preferences regarding sonic alignment, both the unaligned (x,y,z) and the aligned (u,v,w) sonic signals are present in the published time series file. In addition, a sonic speed signal and sonic direction signal derived from the transformed (u,v,w) components are written to the data file.

Due to ambiguity with respect to sonic axis definitions and often in-complete knowledge of the physical orientation of the sonic, it was decided not to attempt to treat the sonic direction as an absolute quantity. Instead the mean sonic direction is always zero and only the standard deviation is available as a statistic. Co-variances, rotation angles and friction velocity are written to the time series header as additional statistics. These are listed in Figure 4.4-2.

i U: component in mean wind direction; ◁U▷ 0.0 m/s; [signal type = su].

ii V: horizontal component perpendicular to mean wind direction; ◁V▷ = 0.0 m/s; [signal type = sv].

iii W: vertical component perpendicular to U,V plane; ◁W▷ = 0.0 m/s; [signal type = sw].

iv Sonic speed: $S = Sqrt(U^2 + V^2)$; [signal type = ss]

v Sonic direction: R = Atan(U/V) - Note that the absolute direction is not preserved and consequently the mean value is not recorded in the database. Standard deviation is however valid. [signal type = sd]

vi [additional statistics] are supplied with 6 co-variances, the rotation angles and the friction velocity:
sonic co-variance u-v
sonic co-variance u-w
sonic co-variance u-t
sonic co-variance v-w
sonic co-variance v-t
sonic co-variance w-t
sonic co-variance w-t
sonic anemometer co-ordinate rotation about z-axis

Figure 4.4-2: Available sonic signals.

4.5 Data screening

Documented data quality control is a major feature of the database. The present Section describes the various stages in the screening and how the results of this process are stored in the database.

The data screening process for the *time series* data consists of 8 steps, which are performed *before* the data are entered into the database as listed in Figure 4.5-1.

i	st.dev. > 0.0: test for active sensor.
ii	|max-min| < 6 × standard deviation.
iii	normalised statistical forth order moment is calculated and checked (>1.5 and < 5.0)
iv	normalised statistical sixth order moment is calculated and checked (>8.0 and < 20.0)
v	signal minimum and maximum values are checked according to specified instrument upper and lower measurement values. Note, that the instrument upper and lower measurement values are entered through the master sensor table.
vi	detection of possible signal noise.
vii	detection of possible signal spikes.
viii	detection of possible level jumps.

Note, that no cross screening are performed

Figure 4.5-1: The data screening process.

The motivation for the selected screening items is summarised below with reference to the nomenclature introduced in Figure 4.5-1.

- i is used to ensure that only active signals are registered and used in the database.
- ii is used to ensure that extreme ranges correspond to "something" like a normal distribution - failure in this check item indicates possible spikes.
- iii range checking of a normalised 4th order moment.
- iv range checking of a normalised 6th order moment.
- v range checking the signal according to instrument specifications.
- vi possible noise.
- vii possible spikes.
- viii possible signal level jumps.

The central features of the screening items are to ensure a reasonable and documented data quality. The results of the screening process are included in the database as binary information (False/True = -1/1) and in addition some of the computed scalars.

The *resource* data screening includes only range checking according to instrument specifications.

4.6 Data indexing

The purpose of the data indexing is to generate suitable descriptive statistics of the time series, which can subsequently be used as selection parameters, in order to pick out relevant time series. Obviously the choice of indexing parameters strongly reflects the intended use of the wind data. The selected indexing parameters, stored in the database, are described in the succeeding subsections.

4.6.1 Run and "nominal" statistics

Basic statistics (mean, standard deviation, minimum and maximum) are generated for all channels both at the run (varying between 600 and 3600 seconds) and at the 10-minute level. A further reduction is made by generating "*run* nominal" values for wind speed, wind direction and turbulence intensity by taking a simple mean of all the channels of the relevant signal type, regardless of sensor height. "Nominal speed", for example, is the mean of all the wind speed channels for a given run, "nominal direction" is analogues the mean (with correct 360-0 handling) of all the wind direction channels and "nominal turbulence intensity" is the mean turbulence intensity for all the wind speed channels. These 3 nominal values give a very concise picture of the entire time series and are appropriate for simple queries.

4.6.2 Ten minute indexing

Indexing of data are performed in a number of different steps depending on the actual signal type. The basic period for all indexing purposes is 600 seconds as opposed to the actual run duration (varying from 600 to 3600 seconds) for run and "nominal" statistics. The results from this data indexing process are included in the search databases and used in the *advanced queries*. Only time series with nominal wind speed above 3.0 m/s are indexed since low winds are not of interest in terms of wind induced structural loading. For gust and acceleration parameters, the time window constants used are Δt = 2, 5, 10 and 30 seconds. For time series scanned with low frequency ($\leq$ 2 Hz) only Δt =5,10 and 30 are used.

4.6.3 Basic statistics

The calculated main statistics referring to a 600 seconds basic period are:

- i Mean value;
- ii Standard deviation;
- iii Minimum value;
- iv Maximum value;
- v Turbulence intensity (for U > 0);
- vi Stationarity factor (trend variance contribution (for U > 0)), for an assumed linear trend defined by h, is determined as $h^2/12$;
- vii Trend corrected turbulence intensity (for U > 0) is expressed as $100/U*Sqrt(\sigma^2_{total} - h^2/12)$ [%].

4.6.4 Wind speed gusts

The *maximum* wind speed gust size (within the 600 second basic period), S_G, is determined for 4 different gust reference periods, Δt = 2, 5, 10 and 30 seconds. The applied gust definitions are given below (and are further illustrated in Figure 4.6-1):

- i Positive gust size, $+S_G$, is detected as $\max[S_{t+\Delta t} - S_t]$ for $t \in [0;600s]$;
- ii Negative gust size, $-S_G$, is detected as $\min[S_{t+\Delta t} - S_t]$ for $t \in [0;600s]$,

where S_t denotes a wind speed signal recorded at the time t.

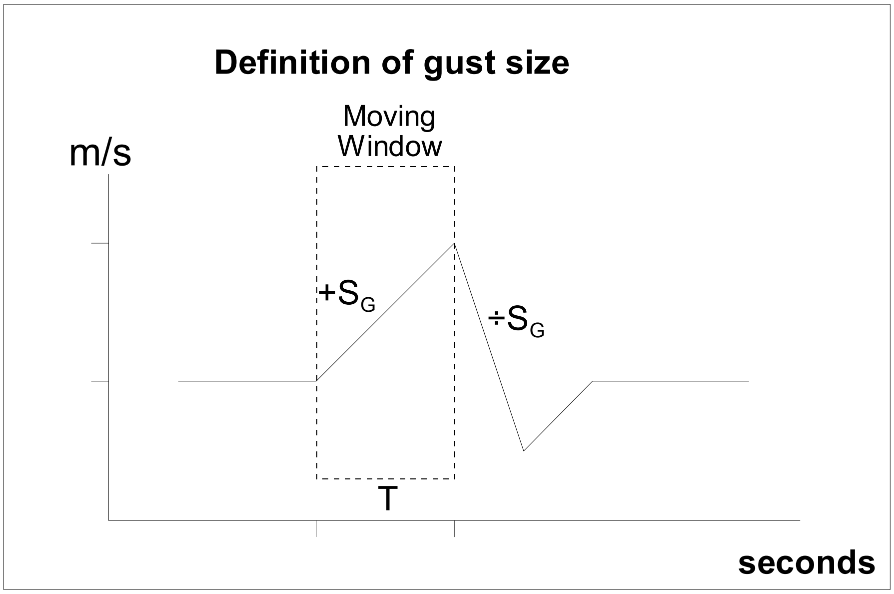

Figure 4.6-1 Gust definition.

4.6.5 Wind acceleration gust

The *maximum* wind acceleration (within the 600 second basic period), S_A, is basically also determined for 4 different gust reference time periods, ƛt = 2, 5, 10 and 30 seconds. However, for time series scanned with low frequency (ℂ 2 Hz), only the reference periods ƛt = 5,10 and 30 apply. In the present context the wind acceleration gusts are defined by:

i Maximum positive acceleration, $+S_A$, during the period ƛt is determined as max($[S_{t+ƛt} - S_t]$/ƛt) for t ⊙ [0;600s];

ii Minimum negative acceleration, $-S_A$, during the period ƛt is determined as min($[S_{t+ƛt} - S_t]$/ƛt) for t ⊙ [0;600s],

where S_t denotes a wind speed signal recorded at the time t. For each ƛt, the values of $+S_A$ and $-S_A$, identified for each basic time period (600 seconds), are stored in the database.

4.6.6 Wind direction gust

The *maximum* change in wind direction (within the 600 second basic period), D_G, is defined by

D_G = max($|D_{t+ƛt} - D_t|$) for t ⊙ [0;600s]

where D_t denotes a wind direction signal recorded at the time t. In analogy with wind speed gusts, the wind direction gust D_G is determined for 4 different gust reference periods, ƛt = 2, 5, 10 and 30 seconds. For time series scanned with low frequency (ℂ 2 Hz) only ƛt = 5,10 and 30 are used. For each ƛt, the values of D_G, identified for each basic time period (600 seconds), are stored in the database.

4.6.7 Wind direction angular velocity gust

The *maximum* wind direction angular velocity (within the 600 second basic period), D_A, is defined by

D_A = max(|$D_{t+ƛt}$-D_t|/ƛt) for t ⊙ [0;600s]

and is evaluated for the same gust reference periods as D_G. For each ƛt, the values of D_A are identified for each basic time period (600 seconds) and subsequently stored in the database.

4.6.8 Gust directional index

The *maximum* value of the Gust Directional Index (GDI) is determined for 4 different periods, ƛt = 2, 5, 10 and 30 seconds. The GDI factor expresses the degree of synchronism of the occurrence of maximum wind speed gust and maximum wind direction change. The GDI parameter is defined as:

$$GDI = \max\left(\frac{|S(t+\Delta t) - S(t)|}{\max(|S(t+\Delta t) - S(t)|)} + \frac{|D(t+\Delta t) - D(t)|}{\max(|D(t+\Delta t) - D(t)|)} \right) \text{ for t ⊙ [0;600s]}$$

Maximum value of the GDI index lies within the interval [1;2]. A value of 1 corresponds to no correlation whilst 2 implies full correlation between the maximum wind speed gust and the maximum wind direction gust. For each ƛt, the values of the GDI index identified for each available basic time period (600 seconds) are stored in the database.

4.6.9 Linear wind shear

The *maximum vertical* wind speed gradient (corresponding to an *assumed* linear wind speed profile) is determined for each of the reference time intervals ƛt = 2, 5, 10 and 30 seconds. The maximum positive, +P_h, and the maximum negative, -P_h, wind speed gradients are in the present context defined by:

i +P_h = max(S_{h2} - S_{h1})/ƛh for t ⊙ [0;600s]

ii -P_h = min(S_{h2} - S_{h1})/ƛh for t ⊙ [0;600s]

where S_{h*} denotes the wind speed recorded at height h*, and ƛh = h2-h1. The maximum vertical wind speed gradients are determined and stored in the database for all pairs of speed sensors satisfying the following criteria:

i Sensors belong to the same meteorological mast;
ii Lower recording level (h1) > 15m;
iii Upper recording level (h2) < 100m;
Difference in sensor levels ƛh > 20m.

4.6.10 Determination of shear factor and exponent

The variation in wind speed with height can symbolically be expressed as

$$S_h = \text{factor} \quad h^{\text{exponent}} ,$$

where h denotes the observation height.

The shear factor and the shear exponent are stored in the database as indexing parameters in cases where the following conditions are fulfilled:

i Wind speeds at 3 or more heights on the same mast are available;
ii The wind speed increases monotonically with height.

If these conditions are fulfilled, the shear factor and exponent are derived from linear interpolation of the qualifying 10-minute mean wind speeds, plotted in a log-log depiction.

5. The SQL database

Every item of information (indexed values and resource data) with the exception of the time series, is stored in the central SQL database. In many ways the SQL database can be considered as the heart of the entire system. The structure of the database is a reflection of the logical entities and processes that have been identified and implemented. Designing the database has been an iterative process deeply linked with the design of the other major components of the system - the input format specifications, data registration, screening, indexing and the web interface. In the following sections, the basic structure of the database is presented and a brief technical description is given.

5.1 Structure of the database

The task of the database is to hold all the information needed for selecting time series together with all the available documentation. Both search flexibility and performance are crucially dependent on the underlying database structure. It has been chosen to split the database into five classes, each containing a number of tables. The classes are:

i Projects;
ii Sites;
iii Instrument;
iv Runs;
v Ten_mins;
vi Scans.

The content of these classes is further explained in Figure 5-1.

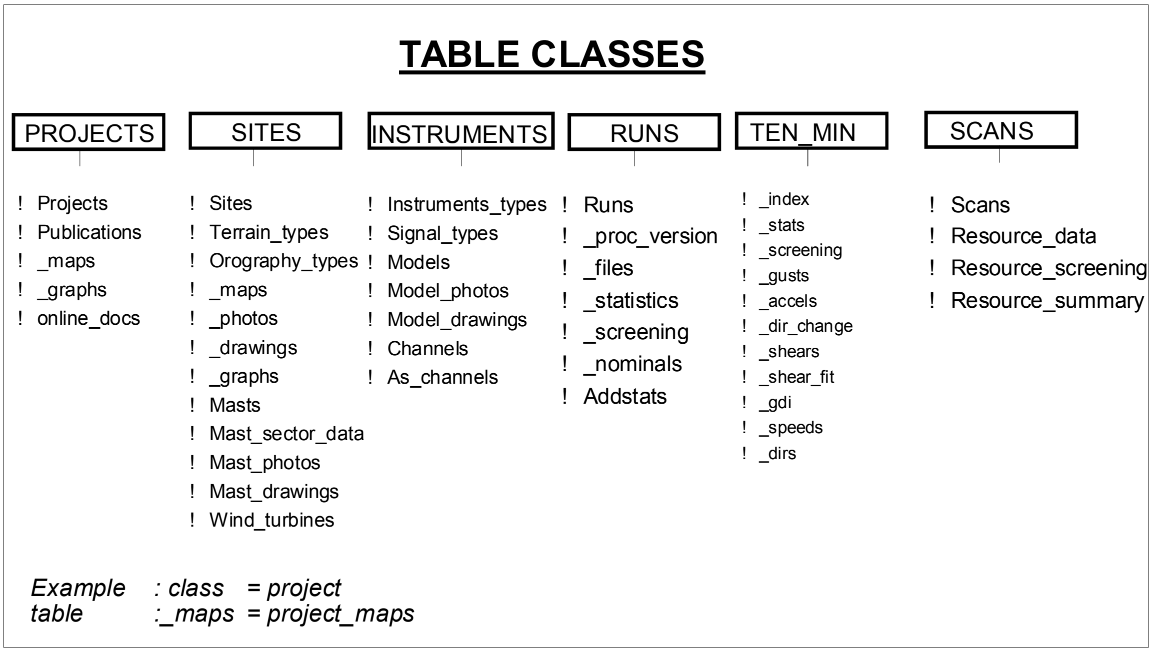

Figure 5-1: Definition of the database project classes.

The first three classes deal with documentation, the next two with statistics and indexing parameters and the last with resource data. In principle a search for data may contain elements from any of at least five classes, in practice only the three or four are used. The classes are further described in the following subsections.

5.1.1 Projects

This class contains the institutional background of the project, i.e.:

i Why the project was undertaken;
ii Who was in charge;
iii Who else was involved;
iv Who funded the work;
v Publications,
vi Documentation relating to the whole project (descriptions, maps and graphs).

A project typically "owns" one but possibly several sites, for example where one experiment is conducted over a region with a number of separate sites.

5.1.2 Sites

This class contains the description of one site, including:

- i Location,
- ii Terrain type;
- iii Orography type;
- iv Graphical documentation relating to the site (descriptions, maps, graphs, photos, drawings);
- v Mast descriptions;
- vi Mast-sector descriptions.

A site "owns" one or more masts and possibly a number of wind turbines. For each mast, the following is described:

- i Location;
- ii Height,
- iii Description;
- iv Roughness data for 12 sectors;
- v Wind turbine wake presence for 12 sectors;
- vi Mast graphical documentation (photos, drawings).

Many wind measurements originate from wind turbine tests or wind park measurements. Wind turbine wakes may be a desired or an undesired feature of the wind data but in any case require documentation. Any wind turbines in the vicinity of the measurement site that can influence the wind data are described, i.e.:

- i Location;
- ii Description;
- iii Diameter;
- iv Hub height;
- v Rated power;
- vi Rated wind speed.

5.1.3 Instruments

For the instruments, it is important to distinguish between *model*, *instrument*, *signal, mounting and channel*. The following definitions have been set up:

- i **Model:** A specific type of instrument from a specific manufacturer;
- ii **Instrument:** One particular example of a given model;
- iii **Signal:** One parameter (of possible several) from a given model;
- iv **Mounting:** Where and how a particular instrument is mounted;
- v **Channel:** A given signal from a given instrument at a given mounting.

An example may help to clarify these definitions: - **channel** *SY_43m* consists of the *Y axis speed* (**signal**) from a *Gill Solent R3 Sonic Anemometer* (**model**), *serial number 234* (**instrument**) mounted at *43m on mast 3* (**mounting**).

Once these definitions and distinctions are understood, a logical form for documentation can be devised. Starting with a *model*, these has the following essential properties:

Manufacturer;
Model specification;
Type (e.g. cup, vane, sonic);
Physical properties (weight, dimensions);
Graphical documentation (drawings, photos, wiring diagrams);
Signals (output parameters).

Signals are defined in their own table with the following basic properties:

Type (e.g. speed, direction, …);
Time or length constant;
Range;
Accuracy.

One physical manifestation of a given model is defined as an *instrument.* Its physical properties and output parameters are already defined in the *models* and *signals* tables. The properties specific to a particular instrument is what is important here:

Serial number;
Data of purchase;
Date of last calibration;
Service record.

Information on precisely where a particular instrument is used appears from the *mounting* table with the following essential properties:

Mast;
Height;
Boom or top mounted;
Boom properties (length, depth, form, direction);
Mast dimensions at boom height;
Sensor orientation.

Finally, a *channel* - a given signal from a given instrument at a given mounting - is specified in terms of:

Name;
Instrument;
Signal;
Mounting.

5.1.4 Runs

Two levels of indexing and statistics have been adopted - the run level with simple statistics of a complete run and the 10-minute detailed statistics and, associated with that, index parameters (gust, direction change and shear) for each 10-minute period of a run. In the database structure these two indexing levels are clearly separated. Here the run level is described.

A time series is registered in the *runs* table, where a run is given a unique internal index and the following salient features are recorded:

- i Project and site;
- ii Run name;
- iii Start date and time;
- iv Run duration;
- v Position in time series sequence.

Each time series file (one per frequency per run) is registered in the *run_files* table, with the following specifying features:

- i Frequency;
- ii Number of scans;
- iii File name, size (packed and unpacked) and volume name.

As described in the previous section, statistics at the run level comprise *run statistics* (basic statistics of all channels for the complete run) and *run nominals* (wind speed, wind direction and turbulence intensity statistics condensed from all the sensors of the appropriate type down to one value for each parameter). These two statistics types are contained in the *run_statistics* and *run_nominals* tables. A third table, *addstat,* contains the *additional statistics* data that may optionally be added to the time series file header to document climatology, wind turbine power output or other relevant, non-wind parameters.

Screening performed at the run level is documented in the *run_screening* table.

5.1.5 Ten_mins

All the 10-minute indexing is documented in the *ten_mins* level of the database. Here the central table is *ten_min_index,* where each 10-minute period of each run is registered and given a unique, internal index. Indexing results are stored in the following tables:

Ten_min_stats.
Ten_min_speeds.
Ten_min_dirs.
Ten_min_gust.
Ten_min_accels.
Ten_min_dir_change.
Ten_min_shears.
Ten_min_shear_fit.
Ten_min_gdi.

Note, that *ten_min_speeds* and *ten_min_dirs* contain speed and direction statistics respectively, duplicated from *ten_min_stats* in order to improve query speed (somewhat at the expense of strict database practice). Ten-minute screening is documented in the *ten_min_screening* table.

5.1.6 Scans

All the resource data are registered in the *scans* table, where the scans are given a unique internal index. The following salient features are recorded:

i Project and site;
ii Scan name;
iii Start data and time;
iv Scan duration.

Basic statistical values for all channels are stored in the *resource_data* table and a summary is stored in the *resource_summary* table.

5.2 Technical details

The database is implemented using Inprise (formerly Borland) Interbase SQL server, version 5.1, running under Microsoft NT server 4.0. This product is a compact, yet reasonably well performing database server with close integration to other Borland products used in the project (notably Delphi and IntraBuilder). The Interbase/IntraBuilder solution, Figure 5-2, is performing well, but future development of this package has stopped completely. Furthermore IntraBuilder can not be implemented on new Operating Systems e.g. MS Windows 2000.

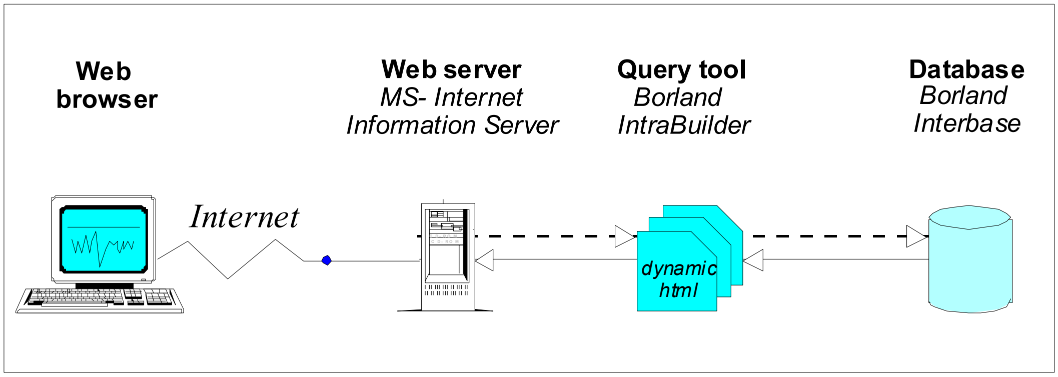

Figure 5-2: Borland Interbase / IntraBuilder / Web server configuration.

The database performance is closely related to the available physical memory. The database server runs on a computer equipped with 512MB RAM, and the database, with a size of approximately 5GB, is stored on a fast 40 GB hard disc.

6. 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.

7. 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 - Users Manual. Risø-R-1300.

[3] Larsen, G.C. and Hansen, K.S. (2001). Database on Wind Characteristics - Contents of Database Bank. Risø-R-1301.

Annex A: Project description

This annex contains a description of the necessary project information. The project information included in the database is based this project description file and prepared as an ASCII text file.

Template for the Project Information File

[Basic_information]
Project_code =
Institution =
Person =
E_mail =
URL =
Address =
Telephone =
Telefax =
Collaborators =
Funding_agencies =
Project_start_date =
Project_end_date =

[Project Motivation]
Free text with an unlimited number of lines

[Measurement_System]
Free text with an unlimited number of lines

[Attachments]
Number_of_publications =
Number_of_maps =
Number_of_graphs =

[Publication_1]
Description =
Reference =
Unlimited number of publications
[Map_1]
Description =
Filename =
Unlimited number of maps

[Graph_1]
Description =
Filename =
Unlimited number of graphs

Description of Project Information File

The name convention for the Project Information File is: "project.pro", which is prepared as an ASCII text file. Note that ";" indicates a comment, which may appear everywhere.

[Basic_information]

Project_code =	Project name - indicating the coordinating project. If a project has only one site, the site_code and the project_code may be identical.
Institution =	Name of institution that primary had the responsibility for the measurement program.
Person =	Contact person.
E_mail =	E_mail address for the contact person.
URL =	WEB page[s] with additional information about this project.
Address =	Postal address of the contact person.
Telephone =	Telephone number to the contact person/ responsible institution.
Telefax =	Telefax number to the contact person/ responsible institution.
Collaborators =	Additional project partners.
Funding_agencies =	List of funding agencies e.g. EU, Ministry of Energy.
Project_start_date =	Start of measurement project (e.g. 1-1-88).
Project_end_date =	End of measurement project (e.g.31-12-89).

[Project Motivation]
The motivation behind carrying out the measurements, given in free text.

[Measurement_System]
Description of the measurement system, given in free text format.

[Attachments]

Number_of_publications =	Number of publications listed below.
Number_of_maps =	Number of maps showing the area of the project.
Number_of_graphs =	Number of relevant graphs associated with the project.

Each of the graphs is supplied with information about the item (e.g. distribution type, period). The preferred format is GIF or JPEG.

[Publication_1]

Description =	Short summary of publication number 1.
Reference =	Reference to publication number 1.

[Map_1]

Description =	Description of the map number 1 (e.g. information about location, scales).
Filename =	Name of file containing the map number 1; preferred format *.GIF, *.JPEG - or other commonly used format.

[Graph_1]

Description =	Description of content viz. on graph number 1 (e.g. measured wind speed distribution, wind roses).
Filename =	Name of file containing 1. graph; preferred format *.GIF or *.JPEG or other commonly used format.

Example of a Background Information File

```
[Basic_information]
project_code =          PO-Mistral
Institution =           INETI
Person =                Ana Estanqueiro
e_mail =                ana.estanqueiro@ite.ineti.pt
URL =                   http://www.ineti.pt/ite/ite.html
Address =               Azinhaga dos Lameiros, 1699 Lisbon ,Portugal
Telephone =             351.1.7162712(ext.2725)
Telefax =               351.1.7163797
Collaborators =         LNEC,IST,EDP,EDA
Funding_agencies =      NATO SfS program, INETI, Ministry of Energy
project_start_date =    01-01-94
project_end_date =      30-09-98

[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.

[Attachments]
Number_of_publications = 3

[publication_1]
Description =           Describes the initial phase of the S. Jorge
experimental campaign.
Reference =             Castro,R.M.,A.I.Estanqueiro,J.G.Saraiva,L.Gomes e
J.M.Ferreira de Jesus(1996a). "Nato SfS project PO-Mistral: Status of the
Experimental Validation Phase". A.Zervos, H.Ehmann e P.Helm(Ed.s).
Proceedings of 1996 EUWEC H.Stephens and associates.  Bedford.

[publication_2]
Description =           Addresses the wind tunnel calibration of the
ultrasonic anemometer digital and analog outputs including the effect of the
tilted incoming flow.
Reference =             Estanqueiro, A. I. e F. Marques da Silva (1996).
Calibration Report of the "Solent-Research model" ultra-sonic anemometer,
INETI/DER-LNEC.(In Portuguese).


[publication_3]
Description =           Describes the INPark model and characterises its
validation campaign.
Reference =             Estanqueiro, A. I., J. M. Ferreira de Jesus e J. G.
Saraiva (1996a)."A wind park grid integration model for power quality
assessment". A. Zervos, H. Ehmann et P. Helm (Ed.s). Proceedings of 1996
EUWEC, H. Stephens and Associates, Bedford.
```

Annex B: Site description

This annex contains a description of the necessary site description including mast and wind turbine information. The site description included in the database is based the available site information.

Template for the Site Description File

[Site_global_data]
Site_name =
Version =
Site_code =
Parent_project =
Longitude =
Latitude =
Altitude =
Country =
Dominant_terrain_type =
Dominant_orography =
No_of_masts =
No_of_wind_turbines =

[mast_1]
x =
y =
z =
Roughness_class =
Turbine_wakes =
Description =

[turbine_1]
x =
y =
z =
Description =
Diameter =
Hub_height =
Rated_power =
Rated_wind_speed =

[Attachments]
No_of_site_maps =
No_of_site_drawings =
No_of_site_photos =
No_of_site_graphs =
No_of_mast_photos =
No_of_mast_drawings =

[Site_map_1]
Description =
Filename =

[Site_photo_1]
Description =
Filename =

[Site_graph_1]
Description =
Filename =

[Site_drawing_1]
Description =
Filename =

[Mast_photo_1]
Mast_no =
Description =
Filename =

[Mast_drawing_1]
Mast_no =
Description =
Filename =

[Wasp]
Orography_file =
Raw_data_file =
Obstacle_file =
Roughness_file =

Common format of the Site Description File

The name convention for the Site Description File is: "site.pro"(e.g. tjare.sit), which is prepared as an ASCII text file. Note, that significant changes in the site characteristics (e.g. new mat. Mast or wind turbines) require a new site description file including a new site_code.

[Site_global_data]

Site_code =	Site name (succinct - used as an overall site reference, where same site_code should be used in all definition files).
Parent_project =	Name of the co-ordinating project (defined in project description file).
Site_name =	Site name including near-by town and/or state.
Version =	Date of creation (format: day-month-year, e.g. 31-12-95).
Country =	Name of country.
Longitude =	Longitude specification of reference point (usually mast 1) [deg, min, sec.dd, E/W].

Latitude = Latitude specification of reference point (usually mast 1) [deg, min, sec.dd, N/S].
Altitude = Altitude specification of reference point (usually the ground level of mast 1) [m].
Dominant_terrain_type = The dominant terrain type as summarised in Table B-1.

Table B-1: terrain types

type	description
bridge	measurements from a bridge
coastal	water and land
forest	forest
ice	snow and ice cover
offshore	open sea
pastoral	open fields and meadows
rural	agriculture with some buildings
sand	sand cover
scrub	bushes and small trees
urban	town

Dominant_orography = The dominant orography according to Table B-2.

Table B-2: Orography types

type	description
flat	flat landscape
hill	rolling hills
mountain	sharp contours - separation expected

No_of_masts = Number of different meteorological mast locations specified in this file. The location, roughness classes and possible wind turbine wake sectors are included for each meteorological mast.
No_of_wind_turbines=Number of near-by wind turbines specified in this file. Include wind turbines which might influence the wind speed measurements (within a distance of approx. 1 km).

[Mast_1]
x = Relative x-co-ordinate of Mast_1 with reference to reference location ; positive => East [m] according to Figure B-1.
y = Relative y-co-ordinate of Mast_1 with reference to reference location ; positive => North [m] according to Figure B-1.
z = Relative z-co-ordinate of Mast_1 with reference to reference location ; positive => Upwards [m] according to Figure B-1.
Roughness_class = Roughness classes for each of 12 sectors as seen from Mast_1 - according to the Wasp definitions - the Wasp sector sizes are defined in Table B-3.

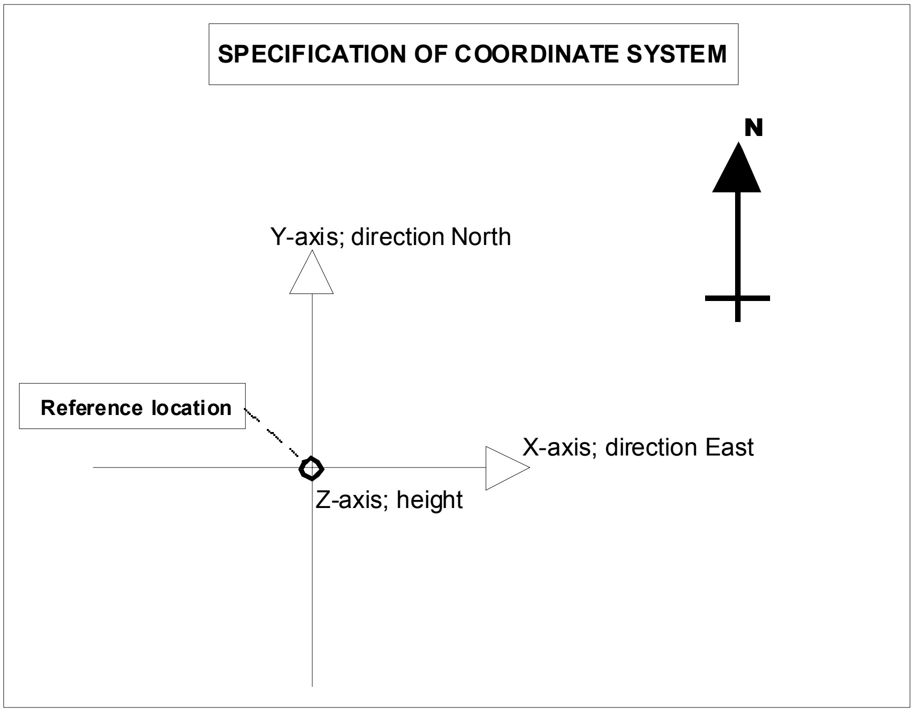

Figure B-1: Mast and wind turbine reference co-ordinate system.

Turbine_wakes = Wake status for each of 12 sectors defined as F[alse] or T[rue] as seen from Mast_1.

Description = Additional information - free text e.g. description of mast type (shape, construction, foundation or guy wires etc.)

Table B-3: Definition of roughness classes

Sector No.	Sector
1	0° ± 15°
2	30° ± 15°
3	60° ± 15°
4	90° ± 15°
5	120° ± 15°
6	150° ± 15°
7	180° ± 15°
8	210° ± 15°
9	240° ± 15°
10	270° ± 15°
11	300° ± 15°
12	330° ± 15°

[Turbine_1]

x =	Relative x-co-ordinate of Turbine_1 with reference to reference location; positive => East [m] according to Figure B-1.
y =	Relative y-co-ordinate of Turbine_1 with reference to reference location; positive => North [m] according to Figure B-1.
z =	Relative z-co-ordinate of Turbine_1 with reference to reference location; positive => Upwards [m] according to Figure B-1.
Description =	Name and type of Turbine_1.
Diameter =	Diameter Turbine_1 [m].
Hub_height =	Hub height of Turbine_1 [m].
Rated_power =	Rated power of Turbine_1. [kW].
Rated_wind_speed =	Rated wind speed for Turbine_1. [m/s].

[Attachments]

No_of_site_maps =	Number of site maps.
No_of_site_drawings=	Number of site drawings.
No_of_site_photos =	Number of site photos.
No_of_site_graphs =	Number of site related graphs.
No_of_mast_photos =	Number of mast photos.
No_of_mast_drawings =	Number of mast drawings.

[Site_map_1]

Description =	Description of the map number 1.
Filename =	Name of file containing the map number 1; preferred format *.GIF or *.JPEG or other commonly used formats.

[Site_photo_1]

Description =	Description of photo number 1 (e.g. viz. the surrounding landscape 0 - 360 degrees with sufficient resolution.
Filename =	Name of file containing photo number 1; preferred format *.GIF or *.JPEG or other commonly used format.

[Site_graph_1]

Description =	Description of graph number 1 (e.g. wind speed distribution, wind rose).
Filename =	Name of file containing the graph; preferred format *.GIF or *.JPEG or other commonly used format.

[Site_drawing_1]

Description =	Description of drawing number 1 (e.g. showing mast and wind turbine positions).
Filename =	Name of file containing the drawing; preferred format *.GIF or *.JPEG or other commonly used format.

[Mast_photo_1]

Description =	Description of photo number 1 (e.g.: viz. mounting details).
Filename =	Name of file containing photo number 1; preferred format *.GIF or *.JPEG or other commonly used format.

[Mast_drawing_1]

Description =	Description of drawing number 1 (e.g. engineering drawings).
Filename =	Name of file containing the drawing; preferred format *.GIF or *.JPEG or other commonly used format.

[Wasp]

Orography_file =	Name of file containing the WAsP inputs.
Raw_data_file =	Name of file containing the WAsP raw data.
Obstacle_file =	Name of file containing the WAsP obstacle definitions.
Roughness_file =	Name of file containing the WAsP roughness information.

Example of a Site Description File

```
[Site_global_data]
site_name =                         sjorge.sit
version =                           27-04-98
site_code =                         S_Jorge
parent_project =                    PO_Mistral
longitude =                         28.57 W
lattitude =                         38.36 N
altitude =                          711
country =                           Portugal
dominant_terrain_type =             coastal
dominant_orography =                mountain
no_of_measurements_location =       1
no_of_wind_turbines =               5
no_of_masts =                       1

[mast_1]
x =                                 0
y =                                 0
z =                                 0
roughness_class =                   1,1,1,1,1,1,1,1,1,1,1,1
turbine_wakes =                     t,t,t,f,f,f,f,f,f,f,f,f
Description =                       Mast  number  one,  located  upwind  to
primary wind direction. Lattice tower with foundation, height 27 m with
instruments mounted on booms, cup anemometers at 10 and 24 m, wind vane at
10m. The sonic anemometer at 27 m is topmounted.

[Attachments]
no_of_site_photos =                 2
no_of_mast_photos =                 2

[site_photo_1]
Description =                       S.  Jorge  Island  physical  model,  LNEC
wind tunnel (topview of the wind park location).
Filename =                          site1.jpg

[site_photo_2]
Description =                       S.  Jorge  Island  physical  model,  LNEC
wind tunnel (view of the island southern coast).
Filename =                          site2.jpg

[mast_photo_1]
Description =                       View of the 24 m cup anemometer and the
top mounted sonic.
Filename =                          mast1.jpg

[mast_photo_2]
Description =                       View of the mast and the whole wind
measurement system.
Filename =                          mast2.jpg
```

Annex C: Master sensor file

This annex contains a description of the primary sensors and the mounting details. The sensor information, which are included in the database, are based on the master sensor file. Sensors added as additional statistics are defined in a separate sensor file.

Template to the master sensor file

[Master Sensor File]
Site_code =
Version =
No_of_sensors =

[Sensor_1]
Sensor_type =
Serial_no =
Manufacturer =
Model_spec.=
Last_calibrated =
Sensor_height =
Boom_direction =
Sensor_direction =
Top_mounted =
Mast_number =
Boom_length =
Boom_shape =
Boom_dimension =
Mast_dimension =
Meas_distance =
No_of_signals =

[Signal_1]
Signal_name =
Signal_type =
Time/Length_constant =
MinMeasVal =
MaxMeasVal =
Units =
Accuracy =

Description of the Master Sensor File

The name convention for the Master Sensor File is: "site.m01"(e.g. tjare.01), which is prepared as an ASCII text file. Note, that significant changes in the sensors (e.g. new sensors, replacement of sensors) require a new description file including new channel names.

Naming convention :	site.mxx
site =	site_name
m## =	## is a sequence number (sensor configuration number) starting with 01 and ending with 99 where "m" indicates it is a master sensor file, e.g. tjare.m01 - the primary master sensor file for the tjare site. Minor changes in the instrumentation, e.g. moving an instrument are incorporated as a new sensor/signal. Significant changes to the instrumentation are implemented with a new master sensor file, characterised with a new sequence number (e.g. tjare.m02). In this case, sensor and signal names from the previous master sensor file may be re-used. *Note: remember to include a reference to the new master sensor file in the [Common File Header].*

Instrument and signal identification
An instrument [= sensor] is defined as a measuring device resulting in one or more signals [=channels]. The instrument is referred to by its model type and serial number (e.g. Risø P_1081, SN.1234). The signal from a sensor is assigned a channel name, which is used in the data files as part of the section named [Sensor Statistics].

Comments
Comment lines are marked with ";" at the first position. Comments may be included anywhere in the file.

[Master Sensor File] - required information (indicates file_type)

Site_code =	Site name (succinct - used as an overall site reference, where a unique site_code are used in all files).
Version =	Version date day-month-year (e.g. 8-7-96 = 8 July 1996).
No_of_sensors =	Number of sensors defined in this file.

[Sensor_1]
The following 6 lines are necessary and required for each sensor in the master sensor file:

Sensor_name =	Data providers name of the sensor. The sensor_name must be unique within this master sensor file. The signal_name and the sensor_name of a given sensor can be identical.
Sensor_type =	Type of instrument, according to the valid instrument types listed in Table C-1.

Table C-1: Instrument types.

Type	Description
cup	Cup anemometer
cuva	Combined cup/vane
hotw	Hot wire, 3 dimensions
hum	Psychrometer
inclin	Speed inclination registration system
pitot	Pitot tube
pres	Barometer
prop	Propeller anemometer
propv	Propeller-vane, combined
rad	Pyrometer
rain	Precipitation, rain measurements
seac	Sea current registration system
sonic	Sonic anemometer
term	Thermometer
vane	Wind direction vane
wave	Wave height recorder
wtl	Wind turbine loads
wto	Wind turbine operational parameters

Sensor_height = Instrument height above ground; required [m].
Boom_direction = Boom direction with reference to North; required [deg].
Sensor_direction = Sensor direction [Free text].
Top_mounted = T [= True] or F [= False] ; indication of whether the sensor is mounted on top of the mast.
Mast_number = Mast number, referring to mast number defined in the site description file; required [-].
Boom_length = Distance between instrument and mast centreline, defined on Figure B3-1. *Note: boom_length = 0 for a top mounted instrument.*
Boom_shape = Shape of boom (e.g. circular, square, ..).
Boom_dimension = Equivalent boom "diameter", equal to side-length facing the wind.
Mast_dimension = Side length (or major diameter) of the mast at measurement height.
Meas_distance = Distance between measuring point (= plane) and the upper surface of the mounting boom, according to Figure B3-1.

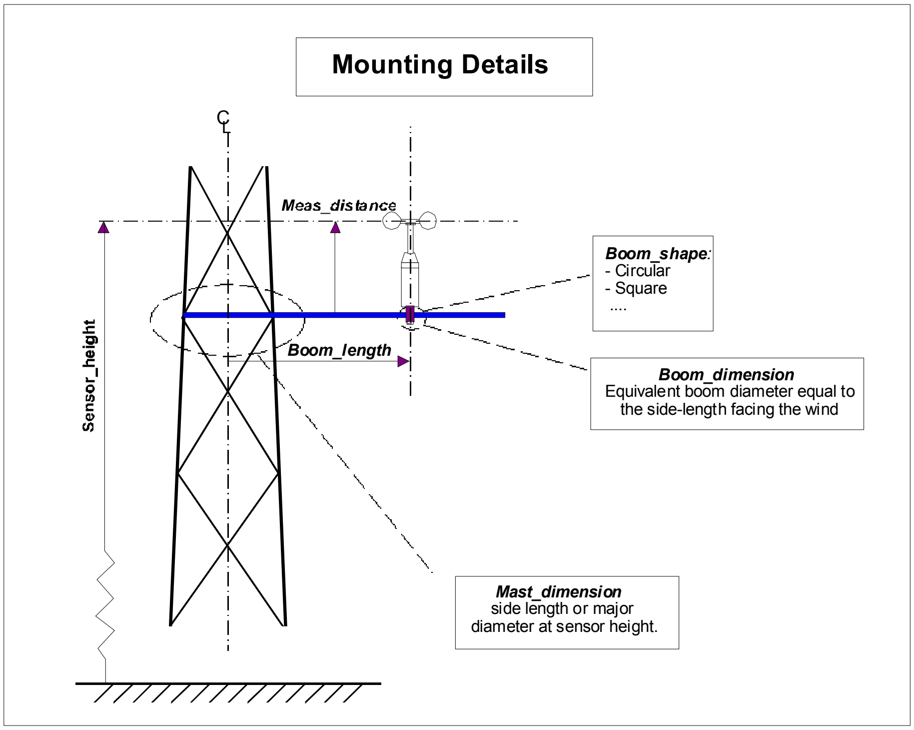

Figure C-1: definition of mounting details.

Serial_no =	Serial number of instrument.
Manufacturer =	Manufacturer of instrument.
Model_spec. =	Specification of instrument.
Last_calibration_date =	Calibration date for instrument.
No_of_signals =	Number of signals originating from this instrument.

[Signal_1]

Signal_name =	Unique signal name.
Signal_type =	Type of signal according to Table C-2.

Table C-2: Signal types

Signal types	Description	Units
acc	acceleration	m/s**2
ahum	absolute humidity	kg/m**3
baro	barometric pressure	hPa
bm	bending moments	kNm
cvut	sonic covariance u-T	~Km/s
cvuv	sonic covariance u-v	m**2/s**2
cvuw	sonic covariance u-w	m**2/s**2
cvvt	sonic covariance v-T	~Km/s
cvvw	sonic covariance v-w	m**2/s**2
cvwt	sonic covariance w-T	~Km/s
cx	current [sea], x-direction	cm/s**2
cy	current [sea], y-direction	cm/s**2
d	wind direction	deg
db_on	wind turbine disc brake on	Volt
f	force	kN
grad	global radiation	W/m**2
nrad	net radiation	W/m**2
pa	pitch angle	deg
pitd	wind speed based on dynamic pitot tube measurement	m/s
pow	wind turbine power (active)	kW
powa	wind turbine power (active)	kW
rain	precipitation	mm/hr
rhum	relative humidity	%
rich	Richardson number	-
rpm	rotor speed	rpm
s	wind speed from cup or propeller	m/s
sd	derived, zeroed, sonic direction (mean = 0)	deg
sh	speed from hotwire	m/s
sht	temperature from hotwire	degC
shx	speed from hotwire, x- direction	m/s
shy	speed from hotwire, y- direction	m/s
shz	speed from hotwire, z- direction	m/s
six	sonic inclination, x-direction	deg
siy	sonic inclination, y-direction	deg
spx	speed longitudinal direction (propeller anemometer)	m/s
spy	speed lateral direction (propeller anemometer)	m/s
spz	speed vertical direction (propeller anemometer)	m/s
ss	derived sonic speed (= SQRT(u^2+v^2))	m/s
st	sonic (virtual) temperature	degC
su	sonic component aligned in mean wind direction	m/s
sv	sonic component aligned in horizontal cross-wind direction	m/s
sw	sonic component aligned in vertical direction	m/s
sx	unaligned sonic horizontal component #1	m/s
sy	unaligned sonic horizontal component #2	m/s
sz	unaligned sonic vertical component	m/s
tabs	absolute temperature	degC

tdif	temperature difference	degC
teta	sonic anemometer co-ordinate rotation about z axis	deg
tilt	sonic anemometer tilt	deg
torq	wind turbine shaft torque	kNm
ustr	friction velocity u*	m/s
wave	wave height	m
wt	wind turbine parameter [Volt]	V
yp	wind turbine yaw angle	deg
Note: New signal types has to be agreed on!		

MinMeasVal = Minimum measurement value.
MaxMeasval = Maximum measurement value.
Time/Length_constant = Time or length constant for the instrument i.e. description of the temporal or spatial resolution.
Units = Units according to signal_type in Table C-2.
Accuracy = An estimated signal accuracy.

Example of a master sensor file

```
;============================================================
;     MASTER SENSOR FILE
;     ------------------
;     Site = sjorge  = S_Jorge, Azores
;     Prepared by INETI, Lisbon
;     Modified : 3/6-98 ksh
;
;============================================================
[Master Sensor File]
Site_code =          sjorge
Version =            27-04-98
No_of_sensors =      4

[sensor_1]
Sensor_name =        ws010
Sensor_type =        cup
Sensor_height =      10
Boom_direction =     225
Sensor_direction =   0
Top_mounted =        F
Mast_number =        1
Boom_length =        1.13
Boom_shape =         circular
Boom_dimension =     0.013
Mast_dimension =     0.30
Meas_distance =      0.07
Serial_no =          n.a.
Manufacturer =       NRG
Model_spec.=         NRG#40
Last_calib. =        may 1995
No_of_signals =      1

[Signal_1]
Signal_name =        ws010
Signal_type =        s
Time/Lenght_constant=3m
MinMeasVal =         0
MaxMeasVal =         40
units =              [m/s]
```

```
accuracy =

[sensor_2]
Sensor_name =        wd010
Sensor_type =        vane
Sensor_height =      10
Boom_direction =     225
Sensor_direction =   0
Top_mounted =        F
Mast_number =        1
Boom_length =        0.43
Boom_shape =         circular
Boom_dimension =     0.012
Mast_dimension =     0.30
Meas_distance =      0.14
Serial_no =          n.a.
Manufacturer =       NRG
Model_spec.=         NRG#200P
Last_calib. =        May 1995
No_of_signals =      1

[Signal_1]
Signal_name =        wd010
Signal_type =        d
Time/Lenght_constant=n.a.
MinMeasVal =         0
MaxMeasVal =         360
units      =         [deg]
accuracy   =         Flow distortion due to terrain

[sensor_3]
Sensor_name =        ws024
Sensor_type =        cup
Sensor_height =      24
Boom_direction =     255
Sensor_direction =   0
Top_mounted =        F
Mast_number =        1
Boom_length =        1.13
Boom_shape =         circular
Boom_dimension =     0.013
Mast_dimension =     0.30
Meas_distance =      0.07
Serial_no     =      n.a.
Manufacturer =       NRG
Model_spec.  =       NRG#40
Last_calib.  =       May 1995
No_of_signals =      1

[Signal_1]
Signal_name =        ws024
Signal_type =        s
Time/Lenght_constant=3m
units =              [m/s]
MinMeasVal  =        0
MaxMeasVal  =        40
accuracy    =
[sensor_4]
Sensor_name =        sonic
Sensor_type =        sonic
Sensor_height =      27
Boom_direction =     n.a.
Sensor_direction =   0
Top_mounted =        T
Mast_number =        1
Boom_length =        0
Boom_shape =         circular
Boom_dimension =     n.a.
Mast_dimension =     0.30
```

```
Meas_distance =      0.49
Serial_no =          0173R2
Manufacturer =       Solent
Model_spec. =        Research, symmetric head
Last_calib. =        May 1996
No_of_signals =      6

[Signal_1]
Signal_name =        s27x
Signal_type =        sx
Time/Lenght_constant=60_msec
MinMeasVal  =        -40
MaxMeasVal  =        40
units =              [m/s]
accuracy =
[Signal_2]
Signal_name =        s27y
Signal_type =        sy
Time/Lenght_constant=60_msec
MinMeasVal  =        -40
MaxMeasVal  =        40
units       =        [m/s]
accuracy    =

[Signal_3]
Signal_name =        s27z
Signal_type =        sz
Time/Lenght_constant=60_msec
MinMeasVal  =        -40
MaxMeasVal  =        40
units       =        [m/s]
accuracy    =


;=============================================================
;
;  Aligned sonic channels su, sv, sw added  3-6-98/ksh
;
;=============================================================

[Signal_4]
Signal_name =        s27u
Signal_type =        su
Time/Lenght_constant=60_msec
MinMeasVal  =        -40
MaxMeasVal  =        40
units       =        [m/s]
accuracy    =

[Signal_5]
Signal_name =        s27v
Signal_type =        sv
Time/Lenght_constant=60_msec
MinMeasVal  =        -40
MaxMeasVal  =        40
units       =        [m/s]
accuracy    =

[Signal_6]
Signal_name =        s27w
Signal_type =        sw
Time/Lenght_constant=60_msec
MinMeasVal  =        -40
MaxMeasVal  =        40
units       =        [m/s]
accuracy    =
```

Example of sensor file for additional statistics

```
;============================================================
;     MASTER SENSOR FILE - ADDITIONAL SENSORS
;     ------------------
;     Site   = sjorge  = S_Jorge, Azores
;     Created : 3/6-98 ksh
;
;============================================================
[Master Sensor File]
Site_code =          sjorge
Version   =          27-04-98
No_of_sensors =      1

[sensor_4]
Sensor_name =        sonic
Sensor_type =        sonic
Sensor_height =      27
Boom_direction =     n.a.
Sensor_direction =   0
Top_mounted =        T
Mast_number =        1
Boom_length =        0
Boom_shape =         circular
Boom_dimension =     n.a.
Mast_dimension =     0.30
Meas_distance =      0.49
Serial_no =          0173R2
Manufacturer =       Solent
Model_spec. =        Research, symmetric head
Last_calib. =        May 1996
No_of_signals =      2

[Signal_1]
Signal_name =        s27d
Signal_type =        sd
Time/Lenght_constant=60 msec
units =              [m/s]
accuracy =

[Signal_2]
Signal_name =        s27s
Signal_type =        ss
Time/Lenght_constant=60 msec
units =              [m/s]
accuracy =
```

Appendix D: Template for common file format

This annex contains a description for the common file format used for all data files. The description includes all the main items included in the data files.

Syntax of common file format

[Common File Header]
Site_code =
Date =
Time =
Project_file =
Site_file =
Sensor_file =
Sequence =
Frequencies =
File_names =
Duration =
Sensor_cfg =
Run_name =
Site_name =
Version =

[File Header]
Data_file =
Frequency =
No_of_signals =
No_of_scans =

[Sensor Statistics]
Type, qa, height, wake, name, mean, st.dev. ,min, max, unit.

[Additional Statistics]
Type, qa, height, wake, signal_name, mean, st.dev., min, max, unit.

[Data Field]
x(1,1) x(1,2) x(1,3) x(1,4) x(1,5) ....
x(2,1) x(2,2) x(2,3) x(2,4) x(2,5) ....
....

Description of the Common File format

The name convention for the Common File Format is: "hhmm_fff.dat"(e.g. 1738_250.dat), which is defined on Figure 4.3-1, Section 4.3.

Comments
Comment lines are marked with ";" at the first position. Comments may be included anywhere in the file.

[Common File Header] - required information.

Site_code =	Short name (succinct - used as an overall site reference).
Date =	dd-mo-yy; date when the time series was recorded e.g. 31-12-93.
Time =	hh:mm:ss; time when the time series was recorded e.g. 17:38:12.
Project_file =	Name of project information file [= site_code.pro] with extension "pro" (e.g. tjare.pro = project description for the Tjæreborg project).
Site_file =	Name of site information file [= site_code.sit] with file extension = .sit (e.g. tjare.sit refers to the Tjæreborg site description file).
Sensor_file =	Name of master sensor file [=site_code.m01] with file extension = .m## (e.g. tjare.m01 refers to the Tjæreborg master sensor list).
Sequence =	Number in measuring sequence (e.g. = 2 / 3 means this is the second time series of 3 consecutive time series).
Frequencies =	All available frequencies covering this particular period [Hz].
File_names =	All available files covering this particular period.
Duration =	Duration of time series [seconds].
Sensor_cfg =	Sensor configuration number (e.g. 1).
Run_name =	Runname based in recording time, defined in Reference 2, section 3.2.2.
Site_name =	Site name and country.

[File Header] - required information.

Data_file =	Name of current data file, according to the definition.
Frequency =	Frequency [Hz].
No_of_sensors =	Number of sensors in this data file.
No_of_scans =	Number of scans in this data file.
Version =	Text string with information about post processing performed (e.g. sonic signal alignment).

[Sensor statistics] - required information.
This section contains one row, corresponding to each of the available sensors [=no_of_sensors], which are present in the [Data Field]. The sensor statistics are given in terms of:

Type =	Signal type, referring to the definition in Table C-2.
Qa =	Quality index for the sensor (-1,0 = bad,1 =good).
Height =	Height above ground level [m].
Wake =	Wake status (-1,0 = nowake,1 = sensor inside wake). The wake sectors, referring to a mast, are defined in Annex B.
Name =	Signal_name, according to the master sensor list.
Mean =	Average value of the recorded time series.
St.dev. =	Standard deviation of the recorded time series.

Min = Minimum value of the recorded time series.
Max = Maximum value of the recorded time series.
Unit = Unit of the recorded signal, according to Table C-2.

[Additional statistics] - optional information.
The additional statistics covers signals not present in the [Data Field] which are of significant interest. This output format is identical to the [Sensor statistics]. The signal types are also in agreement with Table C-2.

Type =	Signal type, referring to the definition in Table C-2.
Qa =	Quality index for the sensor (-1,0 = bad,1 = good).
Height =	Height above ground level [m].
Wake =	Wake status (-1,0 = nowake,1 = sensor inside wake). The wake sectors, referring to a mast, are defined in Annex B.
Name =	Signal_name, according to the master sensor list.
Mean =	Average value of the recorded time series.
St.dev. =	Standard deviation of the recorded time series.
Min =	Minimum value of the recorded time series.
Max =	Maximum value of the recorded time series.
Unit =	Unit of the recorded signal, according to Table C-2.

[Data field] - required information.
All data are scaled and stored in physical units [m/s], [deg], [degC] and the numbers are separated with empty "spaces".

Each line contains only one scan with a set of numbers equal to the number_of_sensors given in the [File Header] section.

The number of lines is equal to the number_of_scans given in the [File Header] section.

Example of a data file

```
[Common File Header]
site_code =     sjorge
date =          1- 8-96
time =          18: 8: 0
project_file =  s_jorge.pro
site_file =     s_jorge.sit
sensor_file =   s_jorge.m01
sequence =      1 / 1
frequencies =   40.0000
file_names =    1808_400.dat
duration =      600.00
sensor_cfg =    1
run_name =      199608011808
site_name =     Calheta, S.Jorge Island, Azores, Pt
[File Header]
data_file =     \sjorge\1996\day214\1808_400.dat
frequency =     40.0
no_of_scans =   24000
no_of_sensors = 8
version =       alignment; 1.1a d. 19/3-1997 Hans E. Joergensen
```

```
[sensor statistics]
sx 1 27 0 s27x  -1.71  0.97   -4.7    1.1 [m/s]
sy 1 27 0 s27y  -7.24  0.89  -10.3   -4.3 [m/s]
sz 1 27 0 s27z   1.71  0.79   -0.6    4.6 [m/s]
sd 1 27 0 s27d 226.64  7.40  204.0  247.6 [deg]
ss 1 27 0 s27s   7.51  0.89    4.6   10.4 [m/s]
su 1 27 0 s27u   7.64  0.84    4.9   10.1 [m/s]
sv 1 27 0 s27v   0.00  0.99   -2.9    3.0 [m/s]
sw 1 27 0 s27w  -0.00  0.82   -2.6    2.9 [m/s]
[Additional Statistics]
cvuv 1 27.0 0 cvuv1  0.0583 .0  0.06  0.06 [M**2/S**2]
cvuw 1 27.0 0 cvuw1 -0.1119 .0 -0.11 -0.11 [M**2/S**2]
cvut 1 27.0 0 cvut1  0.0000 .0  0.00  0.00 [Km/s]
cvvw 1 27.0 0 cvvw1 -0.0258 .0 -0.03 -0.03 [M**2/S**2]
cvwt 1 27.0 0 cvwt1  0.0000 .0  0.00  0.00 [Km/s]
cvvt 1 27.0 0 cvvt1  0.0000 .0  0.00  0.00 [Km/s]
tilt 1 27.0 0 tilt1   12.97 .0 12.97 12.97 [deg]
teta 1 27.0 0 teta1 -103.27 .0 -103.27 -103.27 [deg]
ustr 1 27.0 0 ustr1  0.3388 .0  0.34  0.34 [m/s]
[data field]
-1.70 -7.27  1.04 226.83  7.47   7.51  0.01 -0.66
-1.80 -7.50  0.95 226.47  7.71   7.73 -0.03 -0.80
-1.79 -7.53  1.06 226.65  7.74   7.78 -0.01 -0.70
```

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Title and authors

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Pages	Tables	Illustrations	References
51	5	12	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 first part of the Annex XVII reporting, and it contains a detailed description of the database structure, the data quality control procedures, the selected indexing of the data and the hardware system.

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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