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THE ROLE OF A WIND DATA BANK IN THE DEVELOPMENT OF WIND ENERGY IN BRAZIL

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***Abstract.** Technical and economical viability studies are important to any enterprise. These studies are even more necessary with reference to a wind farm implementation – an expensive, high risk and long-term project. The aforementioned studies are heavily dependent on a precise and long-term description of the local wind regime. In this paper we demonstrate why it is necessary to have a large set of wind data available for use in wind energy applications and we present a novel concept for a wind data bank (Banco de Dados de Vento – BDV), which can be freely and readily accessed by the wind farm designer through the Internet. This is done using a specially designed user-friendly interface, which enables the user to work in two levels: the default mode, using standard data, and the interactive mode, which allows for more complete and updated data.*

***Keywords**. Wind energy, Wind Data, Wind Data Bank, Statistical Treatment of Data, Weibull Distribution.*

1. Introduction

The ever-changing weather poses a real challenge to the planner of a wind farm since such an enterprise requires huge investments, careful planning and, especially, because its life span is about 20 to 30 years; a crucial input to technical and economical viability studies is the knowledge of how the wind regime will behave during the lifetime of the wind farm. No investment bank will approve a project without an analysis showing a minimum assurance about the future energy production of the wind farm.

The time evolution of the local wind regime of a given region can be forecast on the basis of its past behavior and it can be defined through statistical and correlation analyses. These mathematical tools enable a wind energy specialist to get an insight into the future behavior of the wind regime and, as a consequence, into the future wind farm energy production.

To correctly define a local wind regime it is necessary to collect wind data for a long period of time, but the wind farm planner cannot afford to wait for such a long time. As an alternative, he can use the wind data stored in wind data banks. A concept of such a data bank is described here; it furnishes wind data used as input to algorithms and statistical procedures for predicting the local wind regime within reasonable error bounds. Three main characteristics of the proposed wind data bank are:

- it has to be easily accessible,
- it has to be frequently updated to capture the most recent behavior of the wind regime,
- the range of the data stored has to be long enough to capture the time history of the wind regime

In this paper we propose a novel concept for a wind data bank that can be freely and readily accessed by the wind farm designer or any other user through the Internet; in addition, we also show the need for a large set of wind data readily available for users involved in wind energy applications. Meteorological and engineering applications may also benefit from this data bank. The proposed wind data bank is complemented by a specially designed user-friendly interface which may be downloaded from a main server. This interface enables the user to work in two levels: the default mode, using standard data, and the interactive mode, which allows for more complete and updated data. From now on, this wind data bank will be referred to as BDV, which stands for "Banco de Dados de Vento" in Portuguese.

2. Viability Studies

In order to better illustrate the need for a wind data bank with the aforementioned characteristics we present the most important steps to be followed by a wind farm planner. It is understood that these steps have no clear boundaries and one activity listed in one step can, and very often are, executed in a previous step or in a subsequent one.

2.1. Regions

The identification of an adequate region to install a wind farm is of foremost importance. A key parameter for this identification process is obviously the annual mean velocity, which can be obtained using the maps and wind atlas already available. However, a data bank (as proposed here) that is continuously updated and can be easily and readily accessed using the internet would be preferable.

2.2. Macrositing

Within the chosen regions, the next step is to identify the promising sites for the wind farm installation. At this point several important aspects of different nature have do be considered, they are:

- availability of the sites for the wind farm installation;
- need for the energy to be generated;
- existence of other sources of energy;
- existence of main transmission lines and their capability to absorb new amounts of energy;
- existing roads and means of transportation of large pieces of equipment, such as parts of the wind turbines;
- local topography, which is important for the assembling and operation of the wind farm and which has a strong influence on the wind regime;
- wind regime itself.

To assess the wind regime, the maps and wind atlas may not offer the accuracy needed; they present interpolated data, both measured and calculated, on coarse grids set up on large regions. It is important to point out the fact that the wind power is proportional to the cube of the wind velocity, which means that an error in the wind speed causes errors to the cube in the power output calculations.

Using the data stored in the proposed Wind Data Bank – BDV – as input, computer programs of the WAsP (“Wind Atlas Analysis and Application Program”) type (Mortensen, 1993; Bodstein 2001) can promptly define the local wind regime with little effort.

2.3. Wind Measurement Campaigns

Wind measurement campaigns are important tools used by a wind farm planner; however they are expensive and become more expensive the longer they last. On the other hand, short-term wind measurement campaigns (six months to one year) provide useful information but they do not generate enough data to determine an accurate time history of the wind regime.

An approach to deal with these two opposite tendencies – short-term versus long-term campaigns – is to use the data from a short-term wind measurement campaign and correlate them with data stored in the BDV. This approach allows for a less expensive and less time-consuming campaign and still considers the time history of the wind regime that is embedded in the data stored in the BDV.

To be used in this way the BDV has to be dynamic in its conception and in its operation. In fact, the data from de BDV have to be constantly updated and be readily accessed by any user; in other words, the data base has to be dynamically updated and easily accessible by the final user. This is only possible if the interaction between the BDV and the final user is made through the internet and not through printed material.

It is to be observed that the data stored in the data bank have to cover a range long enough (preferably more than ten years) to capture the time history of the local wind regime and they have to include the most recent collected values to deal with the (recent) weather changes; these recent data are also necessary for correlation analysis to be performed by an advanced final user.

2.4. Micrositing

With all the data collected in the different promising sites, the planner can choose the best site and the best configuration for the wind farm. In fact, the planner has all the information that is needed for determining the performance of different possible wind farm configurations for each site chosen. Numerical simulation of the wind farm operation can be made using the data from the short-term wind measurement campaigns since these data can be correlated with the wind data from the BDV.

Additionally, with the years of data stored in the BDV, the wind farm planner can statistically predict the future weather behavior and make solid projections of the wind energy production during the life span of the wind farm. Also, it is possible to plan in detail all the major events of the wind farm operation, such as the frequency and time for maintenance.

3. Requirements for a Wind Data Bank

Based on the above analysis, we can easily identify the main characteristics required for a dynamical wind data bank; they are summarized as follows.

3.1 Area Covered

The wind data bank has to encompass the whole area of interest. This area has to be strategically divided as to have a minimum number of collecting meteorological towers and, yet, one has to be able to analyze and define the wind regime in every single point in this area using the data base.

3.2 Updating

The data stored in the wind data bank must:

- be constantly updated;
- have a time lag long enough to capture the wind regime time history.

With the yearly addition of new wind data, the parameters that define the local wind regime are constantly updated with data that describe the recent weather changes, in such a way that the most remote (in time) data become increasingly less important. It is important to note however that a range of data long enough must be kept to capture the wind regime time history.

3.3 Stored Data

Besides the data that define the local wind regime, the data bank must have folders for additional data as, for example:

- raw data for possible future needs. These folders contain the data as they are collected by the meteorological stations without any treatment and thus without any influence of the algorithm used for filtering and for statistical treatments.
- data used to define the topology of the meteorological station. The topology, as used here, includes the topography, the roughness and the obstacles; these data are necessary as input for advanced analysis as, for example, the ones based on the WASP software used to extrapolate the parameters that define the wind regime (see also item 3.4 and item 3.5)
- data used to evaluate the wind farm output. Among these data the temperature and local atmospheric pressure are the most important.
- specially designed folders with wind data (not parameters) that describe the wind regime in recent years; these data are used by advanced users for correlation analysis (see also item 3.4 and item 3.5).
- specialized folders containing results of long range statistical analysis. These results are important not only for wind energy production but also for meteorological, agricultural, etc. users.

3.4 User-friendly

Easy access to the data stored in the wind data bank. This is possible with an appropriate structure of the wind data bank, a specially designed user interface and the use of the internet. As a consequence, we may point out that:

- with this strategy we avoid the need for a special distribution system for printed material;
- the utilization of the parameters that define the local wind regime can be done with an interface that executes automatically the most common operations.
- more specialized operations (correlation analysis, extrapolation using WASP type software, etc) can also be performed, by advanced users, using this interface and additional data downloaded from the BDV upon request.

3.5 Output Data

The output of the Dynamical Wind Data Bank must be done by a specially designed interface downloaded by the user. This user friendly interface performs the most common tasks (calculations for the wind regime and weather definitions, energy output, etc.) according to the user's needs and prepare automatically a printable report. All the tasks are performed in the framework of a project that is stored in the computer HD for future use or reference.

Users can have access to additional information for advanced calculations and tasks. This information is downloaded by the user interface upon request.

4. The Concept of the BDV – A Dynamical Wind Data Bank

To the author's knowledge, up to the moment, there is no similar to the proposed wind data bank.

The oldest effort to present a description of the wind regime is a South America map with lines of constant mean wind velocity; this was done by OLADE and became outdated due to the new regional wind maps and the national wind atlas.

These wind maps represent the most recent effort do describe the wind regime in some regions. The nation wide version of the regional maps is the national atlas. These maps and atlas, called "wind data bank" in contrast to the "dynamical wind data bank", represent a tremendous effort and were built using numerical simulations with some measured input data. The drawback that they all present are related with the main characteristics of a dynamical wind data bank.

- a very coarse grid
- printed material with all the consequences :
    : high production costs
    : a very difficult distribution
    : difficulty in updating
    : etc.
- no interaction with the user
- no information for correlation analysis
- no information for analysis that uses software of the WASP type
- etc.

A concept of our wind data bank, BDV, with the requirements mentioned in the previous section is now described. The BDV is a system comprised of three parts, as illustrated in Figure 1.

The first part is the interface between the meteorological station (the collecting data point) and the kernel of the wind data bank.

The second part is the kernel of the BDV, the real data bank in which the wind data from the meteorological station are filtered, statistically treated and properly stored for distribution through the web.

The third part is the user interface, which is properly designed to be user-friendly. Its main function is, in the framework of a project: download of the required data, use this data for the default tasks, store the project in the user HD and, finally, prepare and print a report with the required information. If more complex tasks are needed, an interactive operation between the user and the BDV allows for the download of additional data for the performing of correlation analysis and use of advanced software.

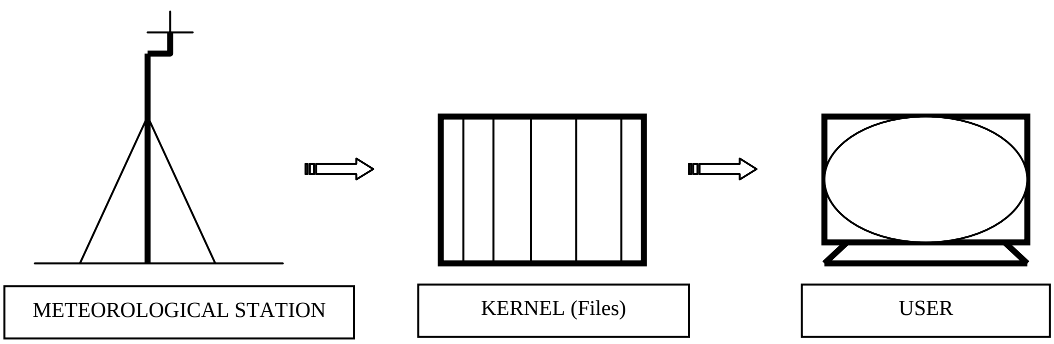

Figure 1. The concept of the wind data bank (BDV).

4.1. The Interface Between the Meteorological Station and the Kernel

The interface between the meteorological station and the kernel of the wind data bank is a complex system used for updating the files of the data bank. The main complexities of this interface are associated with:

- the continuous streaming of information exchange between the meteorological station and the BDV; this is necessary in order to keep the files of the data bank always complete and updated. The continuous exchange of information between the meteorological station and the BDV is necessary in order to promptly identify any problem with the wind sensors, with the storing process, with the communication process, etc. One can not afford to have an empty folder associated to a period of time or a folder with corrupted data. On the other hand the BDV filters can statistically identify any possible non expected behavior of the wind regime; this information is transmitted to the meteorological station for further investigations and identification of the possible causes.
- the diversity of format used by the meteorological stations. This diversity requires a special filter for each format in order to convert the received data to a standard format used in the subsequent calculations.
- meteorological stations use different criteria for data collecting, for example: four daily wind speed and direction, wind data for every ten minutes, wind data for every two minutes, etc.
- Each source of data has its own particular way of disposing the collected data: printed material, CD, web, etc.

The input data have to be treated and rearranged into a standard format using specially designed filters; the converting filters. The converted data are stored in a set of files, the Raw Data Bank - RDB.

The data in the Raw Data Bank are used for:

- to fill the files with raw data for future use
- to update the parameters that define the local wind regime
- to prepare the recent wind data folders needed by advance users.

Before used in subsequent calculations the data from the Raw Data Bank are submitted to filters that eliminate the statistically non representative values.

4.2. The Kernel of The BDV

The second part of the BDV – the KERNEL – is the real data bank. The kernel is, by itself, a complex system of procedures programmed as computer routines interconnected by a main program. These routines represent the kernel of a software that run on any MS-Windows PC-type microcomputer with the sole function of processing wind data and storing them on several different types of data files. Here we will concentrate on the description of the main routines and files.

Several groups of files that form the data bank are created as the information flows along the routines of the kernel. The main groups of data files of data bank are:

- the **Raw Data Bank – RDB**: contains the raw data collected by all meteorological stations; these data are converted into a unique standard format and stored in RDB files.
- the **Yearly Data Bank – YDB**: contains the data from the RDB files filtered in order to remove the data that have no statistical significance; the filtered data are then statistically treated and the parameters that define the month wind regime are calculated. They are stored in groups of files that cover one year of data. Each group of files represents a month of the year. The files of this data bank are updated every time that a new bunch of data is received from the meteorological station.
- the **Treated Data Bank – TDB**: the files of this data bank are separated in macro files containing each one year of data; each macro file, by its turn, contains the monthly files of the corresponding year. The files of this data bank have statistical information about the wind speed and direction, etc for every year and they can be accessed, upon request by an advanced user who wants to use correlation techniques, for example.
- the **Available Data Bank – ADB**: contains the parameters that define the local wind regime as well as other additional information needed for the calculation of the power output. The files of this data bank are accessed, in a default mode, by the final user. The parameters that define the local wind regime are determined using data from a fixed period of years (five or ten years, for example) to which the most recent data from the TDB is added. This data bank is updated once a year.
- other data bank – there are other data bank as for example: the data bank with information about the topology in the neighborhood of the meteorological stations, the data bank of the most representative wind turbines with their characteristics, etc.

The information from Raw Data Bank flows automatically along the kernel of the BDV and is stored in the appropriate data banks. This is done by numerical routines that execute well-defined procedures. The main procedures are:

- the format conversion procedures (converting filters): convert the format of the raw data that come from meteorological stations into a unique standard format that is recognized by the procedures that follow; the data are stored in the files of the RDB.
- the elimination procedures (elimination filters): utilize specially designed algorithms to eliminate the data with no statistical significance; these filters utilize the data from the RDB files to convert them into the data stored in the YDB files;
- the sorting package: this group of routines deals only with the most recent incoming data from the meteorological station. After passing through the above-mentioned filters the data are sorted according to several criteria and stored in temporary files; next, routines of the statistical package are used to calculate the parameters that define the monthly wind regime. These data are then stored in the TDB files;
- the statistical package: this set of statistically-oriented algorithms performs several tasks and also utilizes several temporary files. These temporary files are necessary for the calculation of the updated statistical coefficients that define the local wind regime (the Weibull parameters, for example). This is done by considering the most recent data and discarding the oldest ones. The wind regime so defined preserves the influence of the past time development of the wind and, additionally, considers its most recent behavior. The parameters that define the local wind regime are stored in the ADB files;
- the communication package: this package contains the routines used to generate output files to be used by the User-Interface software. This software allows the interaction between the BDV kernel and the final user.

4.3. The User Interface

The user interface must be downloaded by the final user and run on his workstation or PC. A main feature of this interface is its friendly environment. This interface has three main functions:

- to download from the BDV files the data of the meteorological station chosen by the user.
- to perform some basic operations and display the results of these calculations in a pre-defined report
- to establish an interactive dialog between the BDV and an advanced user

All these functions were already described and need no additional comments.

5. Conclusions

The need for clean and renewable sources of energy is a current fact throughout the world. Among the promising non-conventional sources, the biomass, the solar and the wind energies are the ones considered in Brazil. To these three renewable sources of energy we may add the small hydroelectric power plants.

Among those renewable sources of energy one may say that, in a short term, the wind energy is the most promising one due to the already established technology. In fact, the world projections for 2006 are to exceed the value of 79,000 MW. In Brazil, more than 22,000 kW are in operation and 1,400 MW has been already signed by ELETROBRÁS to be in operation before 2008. These values are sufficient to justify the existence of a wind data bank to supply the necessary input to the economical and technical analysis necessary to implement successfully all these projects.

Moreover, it is necessary to know with accuracy the potential for exploring the wind energy in Brazil. This is necessary for a better planning of the use of our natural resources. With the development of the wind data bank it will be possible to achieve two important goals:

- to have a correct view of the present status and of the need for new meteorological stations, so as to cover strategically the whole country.
- to achieve the necessary experience to establish rules and standard procedures for measuring and storing wind data.

A detailed description of the BDV and its routines are in preparation for submission elsewhere. In the mean time a prototype of the BDV was already tested for a short period of time with success.

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