

Using Geographic Information System for Wind Parks' Software Solutions

Adela Bâra, Anda Velicanu, Ion Lungu and Iuliana Botha
bara.adela@ie.ase.ro, anda.velicanu@ie.ase.ro, ion.lungu@ie.ase.ro, iuliana.botha@ie.ase.ro
Academy of Economic Studies, Bucharest, Romania

Abstract—A Geographic Information System can be used in order to store, analyze and predict data regarding wind parks. Such data can refer to the natural factors that can affect the wind turbines, the placement of the turbines or their power capacity. In this paper we discuss the possibility to manage wind parks in Romania, based on the wind speed and altitude of different regions.

Keywords—Geographical Information System, Prediction, Renewable energy, Spatial data, Wind park

I. INTRODUCTION

THE wind is a renewable resource that can produce energy through wind parks (or wind farms) that can be placed on the ground or off-shore (in which case they combine the wind and the waves power).

On one hand the paper [1] concludes that the total amount of wind energy input through surface waves is about 60 TW. But “most mechanical energy input in surface waves may be dissipated within the surface layer of the oceans through wave breaking, and only a small fraction may be transferred to other forms and locations by the mechanisms of wave-wave interaction and wave-current interaction.”

On the other hand modern wind turbines range from around 600 kW to 5 MW of rated power and they are spread all over the world on soil.

Besides the wind, there are other natural resources that offer potential to the renewable energy. There are the conventional ones like sunlight, rain, tides or geothermal heat, and also the new renewable like small hydro, modern biomass and biofuels, which have gained 2.7% of the renewable energy sources and

Manuscript received October 31, 2010.

A. Bâra is with the Economic Informatics Department, Academy of Economic Studies, Bucharest, CO 010552 Romania (e-mail: bara.adela@ie.ase.ro).

A. Velicanu is with the Economic Informatics Department, Academy of Economic Studies, Bucharest, CO 010552 Romania (phone: +40727859782; e-mail: anda.velicanu@ie.ase.ro).

I. Lungu is with the Economic Informatics Department, Academy of Economic Studies, Bucharest, CO 010552 Romania (e-mail: ion.lungu@ie.ase.ro).

I. Botha is with the Economic Informatics Department, Academy of Economic Studies, Bucharest, CO 010552 Romania (e-mail: iuliana.botha@ie.ase.ro).

are growing very rapidly.

A geographic information system (GIS) is used to create, store, analyze and process information from the geometric space using a computer automated process. GIS technology can be used in various scientific fields such as resource management, studies on environmental impact, mapping, planning routes.

In a GIS the geographic data can be represented as raster or vector. There are GIS software that work in either raster or vector mode, although most of them accept both types of formats.

GIS has a unique way of organizing the database. There are two different types of data in the database: one to store spatial distribution of geographic elements (through a system of x, y coordinates or using the longitudinal - latitudinal system) and another to store the attributes of these elements (e.g. the length, the width, the altitude).

This paper will analyze the effects of natural factors that affect the wind energy and give a GIS solution that can be developed in Oracle Spatial.

II. WIND PARKS

A wind park is a group of wind turbines located in the same area and used for producing electric power. Individual turbines are interconnected with a medium voltage power collection system (usually around 34.5 kV) and communications network.

A large wind farm may consist of a few dozen to several hundred wind turbines and cover an extended area of thousands of square kilometers.

Although the energy produced can be quite substantial we must also consider the losses when describing a wind park. In [2] there are made some measurements in the Sotavento Wind Park in Serra da Loba, Spain. They found that losses represent a 2.84% of the energy generated by wind turbines, consumption of CC (Central Control) building represents a 0.32%, and what is left (96.8%) is the energy injected to the 132 kV network.

Also from an economic point of view, there was stated that the cost of energy losses is between 2.95% and 2.99% of the price of the energy produced. In accordance with the CC building, the percentage of its energy consumption varies from

0.33% to 0.34 %.

As shown in [3], models combining an aggregated electrical system with a non-aggregated mechanical system are the most appropriate approach to wind farm models for dynamic simulations of interactions between power systems and wind farms. These models provide high accuracy in many applications like transient and dynamic stability simulation, and they are very efficient with regard to calculation time.

The most important natural factor that can affect the wind turbines is of course the wind (its speed, direction or frequency). Also we must take in consideration the altitude where the wind parks are situated.

III. NATURAL FACTORS AFFECTING THE WIND PARKS

A. Wind speed

Wind generators are practical if the wind speed is at least 16 km/h and there is not a turbulent phenomenon such as

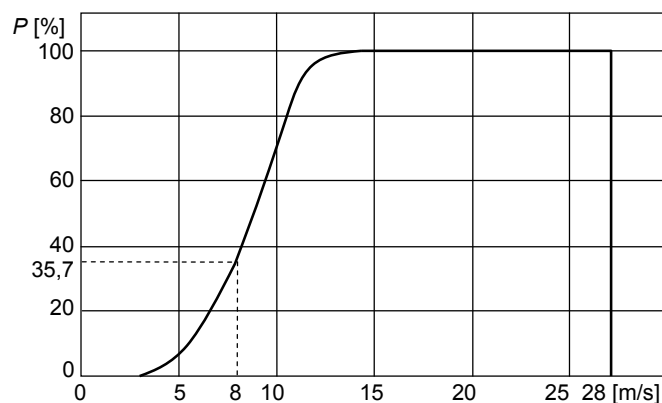


Fig. 1 Power characteristic of a wind generator [4]

The most important measuring tool for a wind turbine is to determine the maximum power that can be taken from the energy of air masses [5]:

$$P_{WA,max} = \frac{8}{27} \cdot A \cdot \rho \cdot v^3$$

where: A – scanned area by the wind generator group paddles;
 ρ – air density ($\rho_{air} = 1,2 \text{ kg/m}^3$);
 v – wind speed.

Note that the power produced in a wind park is proportional to air density, to cubic wind speed and to scanned area by the generator's paddles.

The aim of each wind park is to maximize the produced power by scanning a larger area with its panels and having a higher wind speed (the air density is constant).

A. Altitude

The second factor that can be considered when talking about improving the wind parks is the altitude. This is an indirect factor, because the altitude actually affects the wind, which as

tornados or storms. Having the wind blowing at a constant speed can be more productive than having a fluctuant rising speed.

The paper [4] highlights that the wind power requires a corresponding grid infrastructure, certain technical requirements and back-up rapid power reserve. This power reserve is required both in periods when wind generators are in operation and in decreasing, if they do not work (in this case is necessary an available power that can be quickly turned off if the wind speed falls in the utility limits). The utility limits are less than 3.5 m/s or greater than 30 m/s) and in Figure 1 there can be seen how they affect the power of a wind turbine.

we shown affects the wind turbines.

The wind blows faster at higher altitudes because of the reduced influence of drag. There can be natural obstacles such as forests and valleys in the mountains, and also artificial obstacles which are made by men: buildings or even cities.

So even though the altitude is higher and the wind blows more often here, the surroundings must be considered as well.

IV. GIS

Internationally, we can see a growing involvement in GIS and information management techniques. Areas that already use such techniques in EU countries and also in the U.S. are: agriculture, marketing, investment analysis, cartography, environmental protection, police, army and security services, management of natural and technological disasters, supplying the population with consumer goods and raw materials (gas, oil, etc.), geology, local administration, sociology, health, natural resources, oceanography, regional planning, tourism, waste management, digital phone etc. The mere enumeration of these areas is indicative of the level reached in the

application of GIS techniques [17].

GIS allow you to creating maps, integrating information, visualizing scenarios, solving complicated problems and developing effective solutions. A GIS is a system used for modeling information, processes and structures that reflect the real world, including past events, in order to understand, analyze and manage resources and facilities.

The main purpose of GIS is Spatial Analysis of geographically referenced data and regionalized variables. The informational environment in which the spatial analysis is made is the map, composed of layers and data. For spatial analysis the data must be geographically referenced and inferred the existence of other GIS related functions: acquisition, editing, validation, storage, primary processing, visualization, displaying. Spatial modeling is seen in this case as a special analysis with results like spatial scenarios. Spatial analysis must simultaneously fulfill the following goals: review and interpretation of data, obtain a seemingly hidden information, evaluate the quantitative and qualitative assessment of the entities, processes and phenomena in order to provide practical support for an accurate decision. Making spatial analysis involves the use of analytical procedures, combined with: database management, statistical analysis and geostatistical data, image processing and computer mapping elements [6].

There are three categories of users who can benefit from these systems: business users, scientist users and occasional users. Users of the business world are interested in using spatial data to improve the information underlying the decision of marketing campaigns or of distributing the centers of storage and sale. For scientists, specialized in the study of national resources and geographical environment, spatial data are very important. There is also a third category of occasional users who want to improve their Web applications using spatial data.

Data collecting has long been one of the most expensive procedures in GIS systems. Now, this data gathering process has become faster, easier and cheaper thanks to the development of data acquisition technologies such as global positioning system (GPS) on aerial photographs, automatic or semi-automatic scanners and barcode readers. Because of these new technologies, geographic information systems have evolved from technologies that use less data and little computing power to technologies that use data-rich environments and high computing power.

Many GIS are used to evaluate the impact or performance of different phenomena on the surrounding environment ([7], [8], [9], [10]). Also the paper [11] shows how an integrated GIS and hydraulic model can be able to mix spatial data with hydraulic and quality parameters of the network.

One of the most important benefits of using a GIS is that it can provide forecasting elements. For example in [12] forecasts of wind power production are increasingly being used in various management tasks. Such forecasts and related uncertainty information have usually been generated individually for a given site of interest (either a wind farm or a

group of wind farms), without properly accounting for the spatiotemporal dependencies observed in the wind generation field.

Sometimes more complex techniques and technologies are needed in order to predict the required output. In [13] there are used data mining algorithms, which are the most popular predicting algorithms. The predicted output is the wind power and the specific algorithm chosen is the regression with thresholds.

No matter what techniques are used to obtain the predictions in an energy system these aspects should be considered [4]:

- Most wind generators have at terminals a voltage of 690 V. Each wind generator is equipped with a step-up transformer, and the connections inside the wind parks are performed, usually, at medium voltage (20 kV). From experience, it resulted that losses in a wind park are approximately of 2.5%.
- Backwater effect leads to the decreasing of power of a wind park with approximately 15%.
- Wind speed is a size that significantly differs even within the same emplacement.

Among the most important advantages of using a geographic information system there are:

- data are better organized;
- redundancy in data storage is eliminated;
- update features are facilitated;
- analysis, statistics and new searches are made much easier;
- users are more productive.

Among disadvantages, it should be noted that a GIS system can not run a "what if" scenario. Other applications that are developed to use GIS data can run such scenarios. For example, it is useful if something changes in a network and you want to find out the network's reaction to these changes. Also, GIS systems have the following risks: complexity, high costs, environmental changes, difficulties in training the staff.

One example of a GIS tool is the Golden Software's Surfer. Surfer can create 3D contours and mappings of surfaces. It can convert spatial data in contours, 3D surfaces or frames, vectors, images, landscapes or maps. This product has the followings main options: Contour Maps, 3D Surface Maps, Image Maps, Shaded Relief Maps, Post Maps, 3D Wireframe Maps, Vector Maps, Base Maps, Map Layers, Stacking Maps, Customize Your Map, Superior Gridding, Variograms, Faults and Breaklines, Grid Functions, Using USGS and SRTM Data.

Image Maps feature can be considered the most useful option of the Golden Software Surfer. According to the website presentation of the product ([16]), image maps use different colors to represent the values from a file. Colors are mixed automatically according to percentage values to obtain a uniform gradation of colors for a certain map. Color percentages may change within 0 and 100. It also adds a color scale to show the significance of their associated values.

These maps can be created independently of other maps or can combine different levels of the other maps. Image maps

can be scaled, resized, limited or moved.

Figure 2 illustrates such a map created from a base map of Colorado State and contains the state's sectors and latitudinal levels.

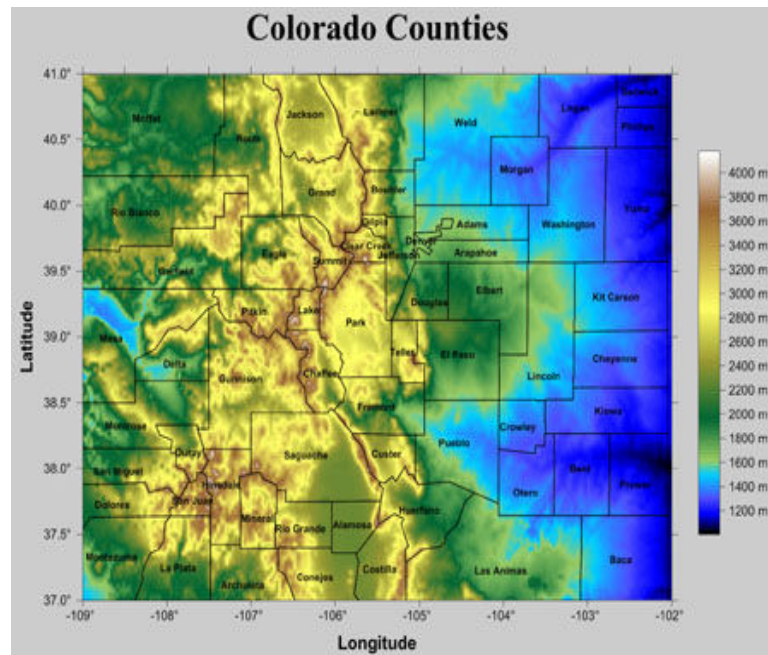


Fig. 2 Colorado map made in Golden Surfer Software (source [61])

Among the main advantages of using image maps in Surfer there are the following features: displaying maps using uniform images and pixels, saving and loading color maps as files created according to requirements, creating an associated color scale for the maps, creating contour maps, base maps or information associated maps, specifying a color for missing data or marking it with a transparent area, changing the angles of rotation, changing the opacity of different layers of maps.

I. IMPLEMENTING SOLUTIONS

In order to implement a GIS for representing the wind parks, spatial (geographical) data has to be determined. The

main elements regarding a wind park could be:

- the position of the park (latitude, longitude);
- the medium wind speed in that area (number of hours/year);
- the altitude of the region;
- description of the wind park (name, number of turbines etc.).

The necessary data regarding the natural factors that can affect wind parks can be obtained from two Romanian maps: one showing the wind energy (Fig. 3 [14]) and the other showing the altitude (Fig. 4 [15]). Both maps must have the same scale.

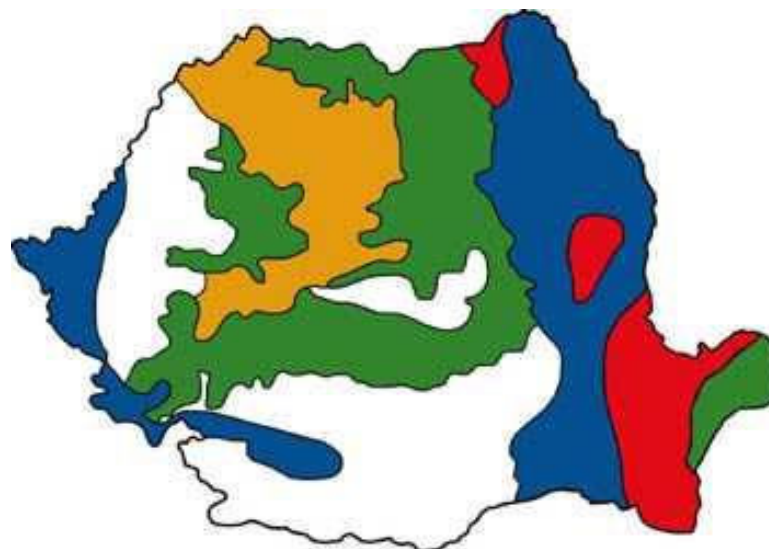


Fig. 3 Romanian Map – areas with wind

In Figure 3 there are 5 types of wind areas determined by the medium number of wind blows in one year:

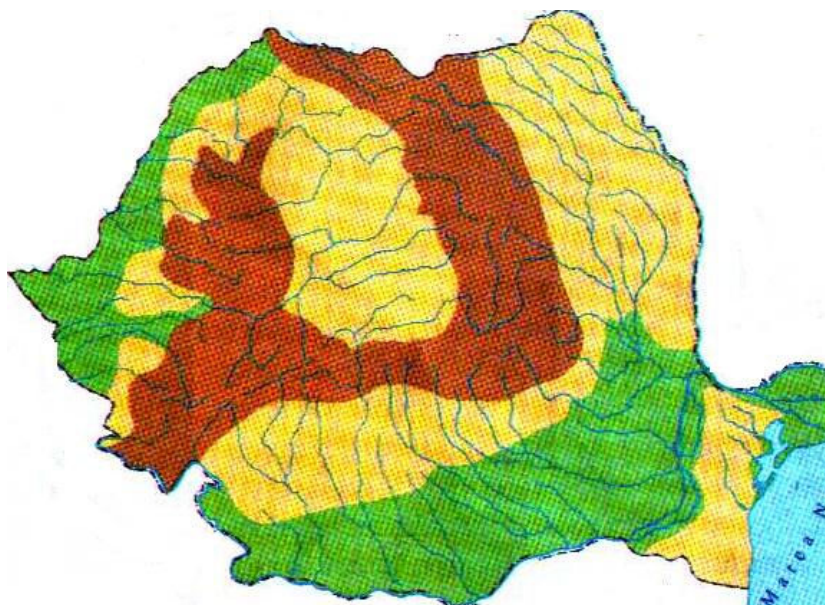
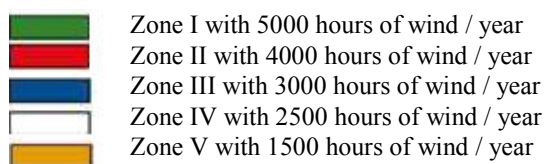
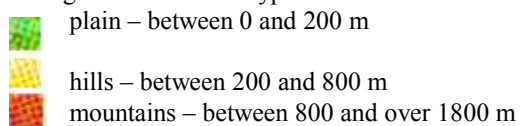


Fig. 4 Romanian map – altitude

In Figure 4 there are 3 types of altitudinal areas determined by their measures in meters:



These two maps are afterwards uploaded in Golden Software Surfer from where data can be extracted (Fig. 5 and 6).

X: 232 Y: 119 Z: 0.44447058823529 Row,Column: 120, 233

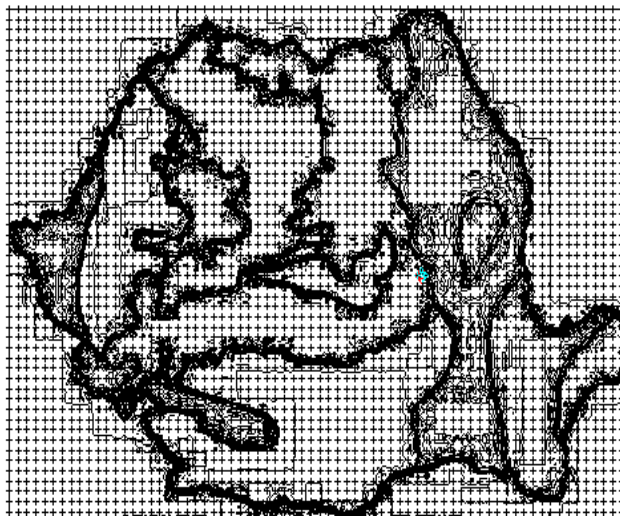


Fig. 5 Wind areas map in Surfer

X: 415 Y: 112 Z: 0.5941568627451 Row,Column: 113, 416

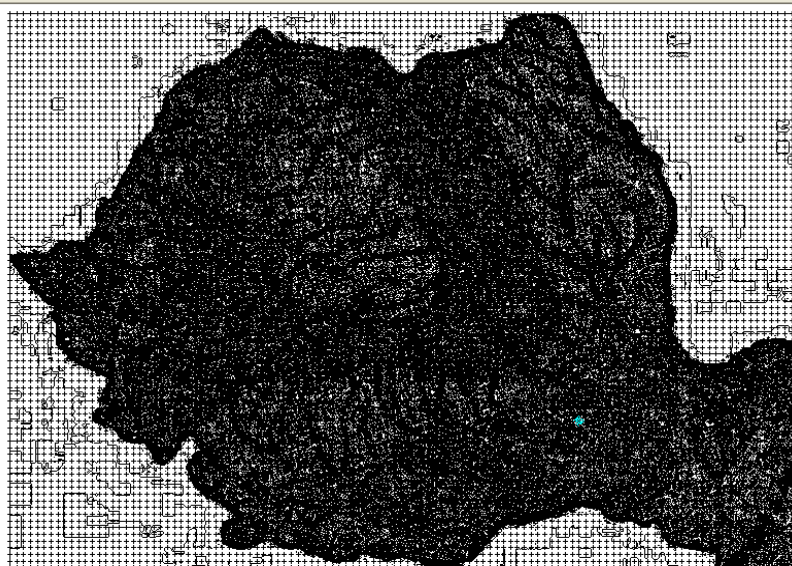


Fig. 6 Altitude map in Surfer

The structure of an Oracle Spatial database table that has to be used in a GIS would be:

```
CREATE TABLE wind_park (id NUMBER(5) primary
key, position SDO_GEOMETRY, wind NUMBER(4), altitude
NUMBER(4), name VARCHAR2(50), turnibe_no
NUMBER(4), creating_date DATE default sysdate, other_info
VARCHAR2(100));
```

For numerical data it was used the NUMBER type, for characters there is the VARCHAR2 type, for dates there is the DATA type and for spatial data there is the SDO_GEOMETRY type.

Three other were included: creating_date which represents data when the wind park started functioning,

other_info which may contain supplementary information regarding the wind park and id which is the primary key of the table.

In Oracle the spatial field has some parameters: SDO_GEOMETRY (polygon_dimension, latitude_longitude, sdo_point_type, SDO_ELEM_INFO_ARRAY (SDO_STARTING_OFFSET, SDO_ETYPE, SDO_INTERPRETATION), SDO_ORDINATE_ARRAYV (variable number of parameters)).

SDO_STARTING_OFFSET represents the offset from which to begin storing in the SDO_ORDINATE vector and starts at 1, not 0.

When creating such a table in an Oracle Spatial application there must be considered the next steps:

1. Create the table in which the spatial data will be stored.
2. Adding the appropriate entries in the table. SDO_GEOMETRY is the spatial field.

3. Updating the USER_SDO_GEOM_METADATA view to reflect the dimensional information for spatial data.

It is required to be performed before the index is created. It is performed once for each level (table-column combination). It contains information about the name of the table that contains spatial data, the column from the table that is SDO_GEOMETRY type, the size of the geometry and a number (SID) which specifies the value of the coordinates system.

4. Creating the spatial index (a R-tree index).

Spatial indexing is a mechanism that helps to increase the search performance on a table based on spatial criteria. An R-tree index approximates each geometry with the smallest rectangle that contains the geometry (called MBR - Minimum Bounding Rectangle). When there are more geometries, an R-tree index consists of a hierarchical indexing of MBR rectangles.

5. Executing spatial queries.

Oracle Spatial is developed by Oracle Corporation, the latest version being 11g Release 2 (2009). Oracle Spatial 10g Release 1 was launched in 2003 and Release 2 in 2005. Oracle has incorporated for the first time capabilities of manipulating spatial data to a version of Oracle Database 4, modified by the scientists who worked for the Canadian hydrographic service. Originally it used a spatial indexing system that involved an adaptation of Riemannian's data hypercube, by invoking a helical coil in a three-dimensional space, which allowed n dimensions characteristics. Later on, the primary indexing system was based on R-tree indexing.

The example proposed in the article is for Oracle Database 10g which contains Spatial and Locator features.

Oracle Spatial is a product of Oracle Database 10g Enterprise Edition that enables developing enterprise spatial information systems, sometimes Web based and wireless locations based solutions, which require complex spatial data management.

Oracle Locator is a product of Oracle Database 10g Standard / Enterprise Edition, which provides a subset of the capabilities of Oracle Spatial, allowing to obtain solutions for Internet applications based on wireless services and geographic information systems for partnerships.

Among the new characteristics of the base nucleus, Oracle Spatial includes GeoRaster. It provides Oracle Spatial package, data types and object-relational schemas in order to store multidimensional grid layers and digital images, which can be referenced by positioning on the Earth or by local coordinates systems [18].

Other new features are: Geocoding, QuadTree index, R-Tree index, new subprograms (SDO_UTIL package), new operators (SDO_JOIN), changes in SDO_NN operator's behavior, LRS (Linear referencing System) subprograms for tolerance, functions for GML (Geography Markup Language)

support, schema MDDATA - default schema for geo coding and routing applications.

The application being developed in this environment will permit users to interrogate the database regarding the existing wind parks and also to perform certain predictions regarding the places where a wind park will better produce renewable energy. The GIS will consider the amount of wind in each region and the altitude which can also affect the wind's intensity and frequency.

CONCLUSIONS

In this paper we presented some implementing solutions for a GIS that helps collect, store, organize and analyze spatial data regarding power plants. We considered the natural factors that influence the power produced by wind power plants (altitude and wind) and we created a database structure that contains the proper attributes.

After we analyzed a few existing GIS that are developed for managing and rendering spatial data for wind parks (including Golden Softer Surfer), we proposed an Oracle Spatial database for Romania's wind parks.

ACKNOWLEDGMENT

This paper presents some results of the research project PN II, TE Program, Code 332: "Informatics Solutions for decision making support in the uncertain and unpredictable environments in order to integrate them within a grid network", financed within the framework of People research program.

This paper is also a result of the project POSDRU/6/1.5/S/11 „Doctoral Program and PhD Students in the education research and innovation triangle". This project is co funded by European Social Fund through The Sectorial Operational Program for Human Resources Development 2007-2013, coordinated by The Bucharest Academy of Economic Studies.

REFERENCES

- [1] W. Wang, R. X. Huang, "Wind energy input to the surface waves", *Journal of Physical Oceanography*, vol. 34, pp. 1276-1280, May 2004.
- [2] E. Diaz-Dorado, C. Carrillo, J. Cidrás, E. Albo, "Estimation of energy losses in a wind park", *9th International Conf. Electrical Power Quality and Utilisation* Barcelona, Oct. 2007.
- [3] M. Poller, S. Achilles, "Aggregated wind park models for analyzing power system dynamics", *Proc. 4th International Workshop on Large Scale Integration of Wind Power and Transmission Networks for Offshore Wind Farms* Billund, 2003.
- [4] S. Oprea, D. Petrescu, M. Anton, "Wind parks' operation in the context of system adequacy", *IEEE PowerTech 2009* Bucharest, June 2009.
- [5] *Wind Energy Handbook*, Wiley Sons, 2001.
- [6] N.F. Braniște, "Geographic Information Systems. Efficiently using geographical information", *IF?? Magazine*, no. 11, pp. 9, 2005.
- [7] M. Abbaspour, A. Soltaninejad, "Design of an environmental assessment model on the effect of vehicle emission in greater Tehran on air pollution with economic sensitivity", *Int. J. Environ. Sci. Tech.*, no. 1 (1), pp. 27-38, 2004.

- [8] M. Abbaspour, A. H. Javid, P. Moghimi, K. Kayhan, "Modeling of thermal pollution in coastal area and its economical and environmental assessment", *Int. J. Environ. Sci. Tech.*, no. 2 (1), pp. 13-26, 2005.
- [9] A. Salman Mahini, M. Gholamalifard, "Siting MSW landfills with a weighted linear combination methodology in a GIS environment", *Int. J. Environ. Sci. Tech.*, no. 3 (4), pp. 435-445, 2006.
- [10] Z. Zerrouqi, M. Sbaa, M. Oujidi, M. Elkharmouz, S. Bengamra, A. Zerrouqi, A., "Assessment of cement's dust impact on the soil using principal component analysis and GIS", *Int. J. Environ. Sci. Tech.*, no. 5 (1), pp. 125-134, 2008.
- [11] M. Tabesh, M. R. Delavar, A. Delkhah, "Use of geospatial information system based tool for renovation and rehabilitation of water distribution systems", *Int. J. Environ. Sci. Tech.*, no. 7 (1), pp. 47-58, 2010.
- [12] J. Tastu, P. Pinson, E. Kotwa, H. Madsen, H. A. Nielsen, "Spatio-temporal analysis and modeling of short-term wind power forecast errors", *Wind Energy*, Apr. 2010.
- [13] A. Bara, I. Lungu, M. Velicanu, S. V. Oprea, "Intelligent Systems for Predicting and Analyzing Data in Power Grid Companies", *The IEEE International Conf. on Information Society (i-Society 2010)* London.
- [14] (Wind Turbines) Available: http://www.ubi-therm.ro/html/turbine_eoliene.html
- [15] (Proportionality) Available: <http://geomap.3x.ro/proportionalitate.html>
- [16] <http://www.goldensoftware.com>, October 2010
- [17] Bălțeanu D., Driga B., Cheval S., Chendeș V., Dumitrașcu M., Ciupitu D.– „Sistem informațional geografic (GIS) pentru studiul dezastrelor naturale”, Academia Română, Institutul de Geografie, http://www.racai.ro/INFOSOC-Project/Balțeanu_st_b08_new.pdf
- [18] Murray C., Blowney J., *Oracle Spatial GeoRaster, 10g Release 1 (10.1)*, Oracle Corporation, 2003

Adela Bâra (M'09) is a Lecturer at the Economic Informatics Department at the Faculty of Cybernetics, Statistics and Economic Informatics from the Academy of Economic Studies of Bucharest. She has graduated the Faculty of Economic Cybernetics in 2002, holds a PhD diploma in Economics from 2007.

She is the author of 7 books in the domain of economic informatics, over 40 published scientific papers and articles (among which over 20 articles are indexed in international databases, ISI proceedings, SCOPUS and 2 of them are ISI indexed). She participated as team member in 3 research projects that have been financed from national research programs. She is a member of INFOREC professional association. From May 2009, she is the director of the Oracle Excellence Centre in the university, responsible for the implementation of the Oracle Academy Initiative program. Domains of competence: Database systems, Data warehouses, OLAP and Business Intelligence, Executive Information Systems, Decision Support Systems, Data Mining.

Anda Velicanu has graduated the Faculty of Economic Cybernetics, Statistics and Informatics of the Bucharest Academy of Economic Studies, in 2008. She is a PhD student in the field of Economic Informatics at the Academy of Economic Studies and since January 2009, she is a Pre-Assistant Lecturer.

She teaches Database, Database Management Systems and Economic Informatics seminars at the following faculties: Economic Cybernetics, Statistics and Informatics, Commerce, Marketing and International Business and Economics. Her research activity can be observed in the following achievements: 5 diplomas, 2 scientific awards, 3 proceedings, 3 articles published in scientific reviews, 2 research contracts, 3 books and 1 research grant. She is a member of INFOREC professional association. Her scientific fields of interest include: Databases, Database Management Systems, Programming, Information Systems.

Ion Lungu is a Professor at the Economic Informatics Department at the Faculty of Cybernetics, Statistics and Economic Informatics from the Academy of Economic Studies of Bucharest. He has graduated the Faculty of Economic Cybernetics in 1974, holds a PhD diploma in Economics from 1983 and, starting with 1999 is a PhD coordinator in the field of Economic Informatics.

He is the author of 22 books in the domain of economic informatics, 57 published articles (among which 2 articles ISI indexed) and 39 scientific papers published in conferences proceedings (among which 5 papers ISI indexed and 15 included in international databases). He participated (as director or as team member) in more than 20 research projects that have been financed from national research programs. He is a CNCISIS expert evaluator and member of the scientific board for the ISI indexed journal Economic Computation and Economic Cybernetics Studies and Research. He is also a member of INFOREC professional association and honorific member of Economic Independence academic association. In 2005 he founded the master program Databases for Business Support (classic and online), who's manager he is. His fields of interest include: Databases, Design of Economic Information Systems, Database Management Systems, Decision Support Systems, Executive Information Systems.

Iuliana Botha is an Assistant Lecturer at the Economic Informatics Department at the Faculty of Cybernetics, Statistics and Economic Informatics from the Academy of Economic Studies of Bucharest. She has graduated the Faculty of Cybernetics, Statistics and Economic Informatics in 2006 and the Databases for Business Support master program organized by the Academy of Economic Studies of Bucharest in 2008. She is a PhD student in the field of Economic Informatics at the Academy of Economic Studies.

She is co-author of two books, 5 published articles (one article ISI indexed and another three included in international databases), 9 scientific papers published in conferences proceedings (among which 3 paper ISI indexed). She participated as team member in 3 research projects that have been financed from national research programs. From 2007 she is the scientific secretary of the master program *Databases for Business Support* and she is also a member of INFOREC professional association. Her scientific fields of interest include: Databases, Database Management Systems, Design of Economic Information Systems, Grid Computing, e-Learning Technologies.