Prototype of a Decision Support System for analyzing and forecasting the Wind Energy Production in Romania

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Abstract: While the development of the new economy conducted to the increase of investors’ interest in all economic fields, the energy system could not remain fully unexploited. Energy produced from renewable resources takes more ground, especially internationally.
In Romania there are major projects in the field of wind energy, considered of great interest today. As we talk of a medium with low predictability, stimulating investors can be achieved also by using decision support systems that receive data from the wind power plants in order to integrate them through specific technologies, to represent them on graphs and interactive maps, to filter and clean them through prediction algorithms, and finally, to provide forecasts with a probability of error as low as possible.
The paper presents theoretical and practical implementation only for the data level, but was highlighted the further integration with other levels. Future research directions assume further contributions to the development of the whole system, with the project research team behind this work.

Key-Words: data integration, XML, spatial data, wind energy, OLAP (On-line Analytical Processing)

1. Introduction

The decision regarding the approval of the Romanian Energy Strategy for 2007-2020, published in Official Journal dated 19.11.2007 [1], stipulate the promotion of energy production based on renewable resources as one of the priorities of the Romanian energy sector development. The decision indicates a growing share of these resources in total gross electricity consumption. Thus, at that time was forecast 33% for 2010, 35% for 2015 and 38% for 2020.
The concept of renewable energy, found in literature as the primary energy represents "the solution of natural energy carriers, without human intervention and transformation, such as: natural fuel energy, hydraulic energy, atmospheric energy, solar energy, geothermal energy, etc." [2].
Renewable energy is a solution to the problems caused by pollution, global warming and reducing traditional resources. However, it has some disadvantages related to the fluctuation of power, irregular spread, usage of a large area of land impact on nature, etc.
According to [3], renewable energy is about 25% of all energy used worldwide. In this category are included, in order of degree of use: hydro followed by wind, biomass, solar and geothermal energy.
The study [4] indicates the existence of a national action plan to promote renewable energy, which is open to public consultation. According to it, green energy is 24% of the total energy produced in Romania. Of total renewable energy, 22% represents thermal energy, 43% electricity and 10% comes from transport. To conduct the national plan there are European funds to support renewable energy projects.
Currently, in our country, there are significant wind energy projects. The study [5] describes the main technical and operating features of power farms:
- The power available in each moment has random values, which can vary between zero and installed power, at the discretion of meteorological factors;
- The technical performances of wind power farms in case of disturbances in the system can be very different, and the experience in use them is practically nonexistent in Romania;
- The volatility and unpredictability of wind power farms production make specific technical problems whose solution induces additional costs for balancing and safe operation of the national energy system.
By its nature, wind energy involves a high degree of uncertainty, both in the system operation and in the planning accumulation of tertiary reserve. An important feature in generating wind power is the need to install additional power into the system which can be capable of providing fast tertiary reserve.
Because it is entirely dependent on meteorological factors, which are highly volatile, the wind energy
is less controllable. Within certain limits, the wind farms production can be predicted, which could provide important information about the amount of energy that can be produced and, especially, about the necessary amount of tertiary energy reserves. The research paper [6] indicates that, although the renewable energy is the energy future of the world, it is necessary to create a new type of infrastructure that permits acquisition and transport of renewable electricity. According to the author, currently only highly developed countries have the financial resources to start such a project, the developing countries continuing to use traditional fuels that are slowly going to be exhausted.

Romania has a huge wind power potential, less explored so far. Although there were concerns for the use of renewable resources, they have started to shy widespread only in recent years, due to investor interest. This is demonstrated by the increase in wind farm projects. A study realized by Erste Bank and presented in [7] positions Romania and, in particular areas such as Dobrogea, Constanta and Tulcea, in second place at European level as the ideal location to build a wind farm.

A big issue in terms of wind energy production is the lack of balance in differences between forecast and actual production. In this respect, differences can be significant, all over the world the wind energy forecast continuing to record very large errors. For this reason it is considered extremely important to have information systems that provide solutions for forecasting and decision assistance.

As we showed in [8] and [9], both nationally and internationally, there are various types of solutions and systems which allow decision making support regarding economic aspects and especially the energy production with a high degree of certainty. These are the cases that allow forecasting and trend analysis with very high accuracy. Problems arise, however, when discussing about environment with low predictability, such as wind power generation, being known cases of failure to implement systems to support decisions under such conditions.

Following research in [3], we have concluded that to ensure these objectives is necessary to undertake a rigorous analysis of the environment, and to design an informatic system architecture, that can use different technologies such as: technologies for data integration from heterogeneous sources, for optimizing data extraction, for analysis and forecasts, and for processing analytical requests.

In summary, the requirements for developing such a decision support system mainly refer to the needs of energy prediction with a high accuracy, data integration from various equipments and local systems, and efficient analysis of energetic and economic resources.

2. Aspects regarding the analysis and design of the proposed informatic system

Following the research from [3], we propose an architecture model for such a decision support system, based on typical architecture of a DSS, but adapted to specific components of information requirements identified in the national energy system.

In the studies [3], [10], [11] and [12], we have already presented and described the architecture of the proposed Business Intelligence (BI) system, which can be applied in the uncertain and unpredictable environments, such as wind energy production and prediction.

The informatic system is primarily intended to assist decision making in the wind energy production and forecast. Energy predictions can be possible only if we record, in a large period of time, data on: weather, produced energy, realized consumption. These data, received in XML format, and also data about wind farms, investors, connection studies, etc., are all stored in a relational database.

As mentioned in [13], the steps followed in implementing BI systems are: initial study and project planning (requirements specification), analysis, design, development, and implementation.

In the requirements specification phase we conducted interviews and discussions with the beneficiaries, in order to identify functional and technical requirements. In this case the main system requirements refer to:
- Management of operational activity. The operators of wind farms regularly transmit data on wind turbines activity, and information about weather conditions, necessary for the forecasting algorithms within the decision support system. Based on these data, decision makers can interact dynamically with the system, receiving reports, graphs, dashboards or geographical representation;
- Management of financial activity. Depending on energy production and green certificates
purchased, the investor may receive incomes, for which rigorous evidence is needed. The analysis phase involves building use-case diagrams, class diagrams and interaction diagrams. In order to realize the system modeling and design, we have use IBM Rational Software Architect CASE tool, as we have shown in [14]. System functionalities are outlined starting from the three activities that have to be managed through the system (the general use-case diagram is included and explained in [14]): financial (management of financial activities), decisional (analysis and predictions), and operational (wind energy production). Starting from the class diagram and using specific techniques to transform UML components in elements of relational databases, we obtained the database conceptual schema shown in Figure 1.

Figure 1 – Conceptual schema of the relational database

3. Aspects regarding the development of the proposed informatic system

Further, we present in the paper some aspects regarding the practical implementation only for the data level of the proposed informatic system’s architecture, but we highlight the further integration with the other levels. The practical solution that we developed integrates several Web technologies specific to the dynamic software applications that characterize the new type of economy. The application is built using Oracle DBMS and specific development tools which natively include Web technologies in their solutions.

The Oracle JDeveloper development environment works with applications that contain one or more projects. A JDeveloper project is a structure that logically groups related files. One application may include several projects in order to organize, access, modification or reuse the source code [15]. For developing the prototype we chose to realize a Fusion Web Application. This application combines technologies such as Java Server Pages, Java Server Faces and XML with templates projects using specific components, such as ADF Faces, ADF Task Flow, and ADF Business Components. An important advantage that brings Oracle JDeveloper programming environment is given by the possibility of using ADF Business Components technology with the multitude of controls and their properties and methods. Practically, it was reached the stage where application developers no longer need to program the actual operations that are now made much easier through certain properties and their methods.

Creating a project that supports Oracle ADF Business Components has allowed us to realize the interaction with the database, through specific views on tables. Furthermore, we have integrated these views into Web pages, which will give opportunities to view and update data in the database.

User interface is implemented using JSF pages (JSP pages with enhanced functionalities thanks to Java Server Faces technology). The navigation between pages is specified by XML documents. In JDeveloper 11g, JSF pages assembly does not require code writing, the programmer having the possibility to define visually relationships between pages, through an XML document (faces-config.xml). This leads to code and application simplification, as an advantage for managing and extending applications with complex interfaces.

We defined the possibilities of browsing the Web pages that we have built in accordance with the
Developing XML schemas for data validation

An XML schema can be defined as an abstract collection of metadata, represented by specific components, such as elements, attributes, complex or simple data types.

In order to specify a standard structure, in accordance with the template of the required data which is received from the operators of wind turbines, we created the tables: date_meteo_t, consum_t and productie_t, based on XML schemas defined below. We also use XML schemas to further validate data in different formats, from various external sources.

Thus, we represented the XML schema related with the structure of XML documents for the production of energy from the wind turbines. Subsequently, we applied the algorithm proposed in [14] to the XML schema, obtaining productie_t table.

Further, in order to implement the defined model in a database, the XML schema is transformed into specific elements. This provides, in fact, the source code for data definition commands (commands belonging to the SQL Data Definition Language):
CREATE TABLE productic_t
(
serie_turbina VARCHAR2(10),
data TIMESTAMP,
viteza NUMBER,
directie NUMBER,
energie_produsa NUMBER,
stare_turbina VARCHAR2(10)
);

The graphical representation of the XML schema previous detailed, is automatically generated using Oracle JDeveloper (Figure 3):

Figure 3 – An XML Schema generated in Oracle JDeveloper

We continued to represent XML schemas corresponding to the structure of XML documents which contain meteorological data and the consumption (in MW). Then we applied again the algorithm developed to the proposed schemas, obtaining the tables: consum_t and date_meteo_t. Subsequently, the data loaded into tables need to be checked to see compliance with the schemas.

Integrating data from the source systems

Wind farm operators can load data into the system using two ways: 1) load source files into the system; 2) complete an online form. In the first case, data can be sent as an XML file, which is loaded on the server, validated against the XML schema and then data are fetched and added to the tables.

After logging into the informatic system, according to their role, the wind power operators can load files containing meteorological data, energy production data or consumption data. Following loading the file on the server, it will be validated in terms of structure. This implies checking the XML structure by comparison with the corresponding XML schema. If the uploaded file is valid, data from XML document will be added to the appropriate table by calling a PL/SQL stored procedure.

Presenting data

Once data is loaded and validated, they can be presented in different formats so that decisions being taken rapidly. Therefore, under the dedicated informatic application section, the investors and other Transelectrica users can view reports, dynamic graphs, dashboards, pivot tables and interactive maps of wind parks.

Figure 4 presents a map created to allow navigation and selection of geographical areas and to notice important information on wind power (current information or forecasts).

Figure 4 – Detail from the wind farms map

In terms of getting useful reports for the decisional process, they are presented in a wide range, from summaries at the connecting stations level to interactive reports, which implement OLAP functionalities or present dynamically the state and value of certain indicators.

Figure 5 presents such a report that implements OLAP features: possibilities of navigation through the hierarchies (based on 1: n relationships between tables) such as drill-down or roll-up; interchange of report elements (which leads to changes in the views over data); selections from the original dataset.

Figure 5 – Dynamic report with OLAP features

4. Conclusions

If the opportunity of the practical contribution (seen in the context of the entire system to be developed and in which the module realized covers only the data level of the four identified) is
obvious, especially for the energy economic environment, the theoretical approaches are particularly appropriate, from teaching and scientific points of view, combining in a comprehensive cutting-edge technological aspects (object-oriented technology, XML standard) with those already established (relational approach). Starting from the analyzed area, interdisciplinary approach has become mandatory in order to develop the prototype of decision support system in environments with low predictability (e.g. wind energy production and forecast).

The impact of the proposed prototype is high given the interdisciplinary approach on the one hand, and on the other the economic part that it implies. Beneficiaries of such research results are: 1) academic and scientific community, through the possibility of applying theoretical aspects, 2) energy system, through the possibility of achieving efficient forecasts, 3) business environment, through the reasons to invest in wind power; 4) universities, as the proposed prototype can apply for teaching purposes.

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5. References