

## Decision Support System in National Power Companies. A Practical Example (Part I)

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*The paper presents the developing stages of the decision support prototype in which the data warehouse and the presentation level are built and validated. The paper also extends the results published in the 12<sup>th</sup> international conference on Informatics in Economy (IE 2013) proceedings and will presents the major steps for developing the data warehouse that integrates the sources from the Wind Power Plants (WPP) from the national parks and also the interface modules that allow managers to analyze data at a central level.*

**Keywords:** Data Warehouse, Business Intelligence, Analytics, Decision Support System

### 1 Introduction

The matter of developing decision support systems has now become a trend in the national companies. The large volumes of heterogeneous data gathered from different types of measuring devices and different formatting sources represent a challenge for developing integration solutions for extracting, transforming and loading data into a central data warehouse from where data can be analyzed and presented through special analytic tools like Business Intelligence (BI). This scenario is the base for our case study and also for the research project in the National Grid Company that has the objective to develop a prototype for decision support system for analyzing the renewable resources like wind power. Also, these aspects have been presented in a limited manner in the paper [1].

The system's architecture consists in four levels: data, model, presentation and telecommunications. The architecture has been presented in previous papers like [2], [3]. The aim of the present paper is to present the developing stage of the prototype in which the data warehouse and the presentation level are built. We'll describe some of the major steps for developing the data warehouse that

integrates the sources from the Wind Power Plants (WPP) from the national parks and also some interface modules that allow managers to analyze data at a central level.

### 2. Considerations regarding data warehouses

The solution adopted for the informatics system prototype that we are going to develop is based on data warehouse implementation using a multidimensional model (MOLAP). The data warehouse built at this stage will allow metrics aggregation and also cubes processing and storage.

Usually the data warehouse architecture varies depending on the specific situation of each organization. For a basic architecture (figure 1), data is loaded from one or more sources, and the users directly access the data warehouse [5].

The architecture of a data warehouse has three main components, as shown in the figure below:

- Data warehouse itself and its management system;
- Data acquisition system from OLTP systems and other sources;
- Data analysis and presentation system.



**Fig. 1** – Main components of a data warehouse  
Source: Authors

A more complex architecture uses integration and cleaning systems and also multiple data mart systems designed for each organization department, as indicated in [5].

As shown in figure 2, such complex architecture is divided into four different levels to achieve the data, as follows: sources, transformations, collections of data, analysis.

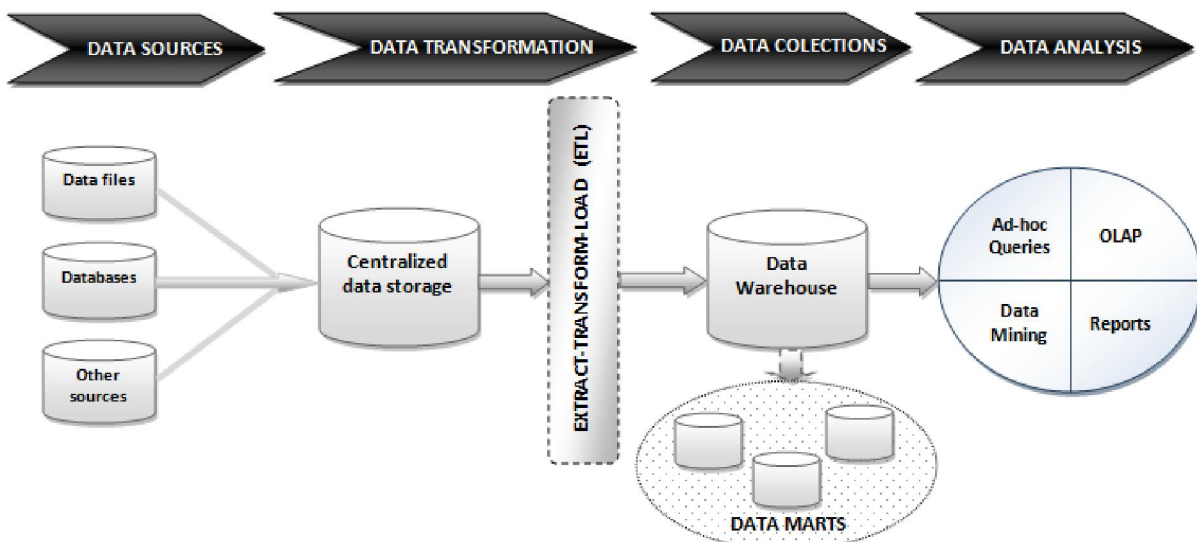
*The data sources level* collects heterogeneous data from various internal or external operational systems of the organization. It uses a process of data integration using a separate module called data source module.

*The data transformations level* uses a process of extracting, processing (cleaning) and data loading (ETL - Extract, Transform, Load), which requires data

processing in terms of: integrity, precision, accuracy, format.

*The data collections level* contains processed data, aggregated and loaded into multidimensional structures on different levels prepared for being used in analysis. At this level we can design multiple data mart systems for enterprise departments.

*The data analysis level* involves extracting data from data warehouse and using business intelligence technologies for the analysis and interpretation of the information provided. At this level are used: OLAP products for analysis (so that data are presented graphically, in spreadsheets, embedded in portals etc.), features for data retrieval using more criteria, data mining products, complex and dynamic reports.



**Fig. 2** – Complete architecture of a data warehouse system  
Source: Authors

From the above architecture we can obtain three functional modules of data warehouse development: operational, central, and strategic [5].

*The operational module* is represented by organizational data which are usually stored in different formats at different locations. These data may come from

applications or operational systems from companies or from external sources. Regardless of their source, the data must be collected and brought into a consistent format to be used. This process of data transformation is the basis for building a consistent data warehouse. Data transformation is a complex process of extracting, filtering, cleaning, compounding, validating and loading data (ETL).

The central data warehouse module is represented by software products, servers on which they run, chosen implementation for the data warehouse. This module can be implemented in two versions: 1) implementation of a distributed system, where data is stored in decentralized, independent units (Independent Data Marts), each containing data relevant to a particular aspect of organization operations; 2) implementation of a unique, centralized data source, which can be accessed by users from all departments of the institution.

The strategic module (business module) offers the final value of a data warehouse

which is due to the advantages offered by the various processes of decision making and analysis. By using different ways to access data and use processing technologies available, users can get information that will help in the process of establishing company strategy. In this way, data are prepared for interpretation and analysis using specific instruments (graphics, presentations, dynamic reports, web browsers, data visualization etc.).

### 3. Developing the data warehouse

As we shown in [1], to implement the model we have chosen Oracle Warehouse Builder 11g development environment (documentation available at [4]) and we have followed specific steps: creating the source module, designing destination module, making mappings, creating and validating objects.

Developing the data source module means actually importing metadata definitions from external sources of data (figure 3). All data sources need to be mapped to the data warehouses objects which are created when designing the destination module.

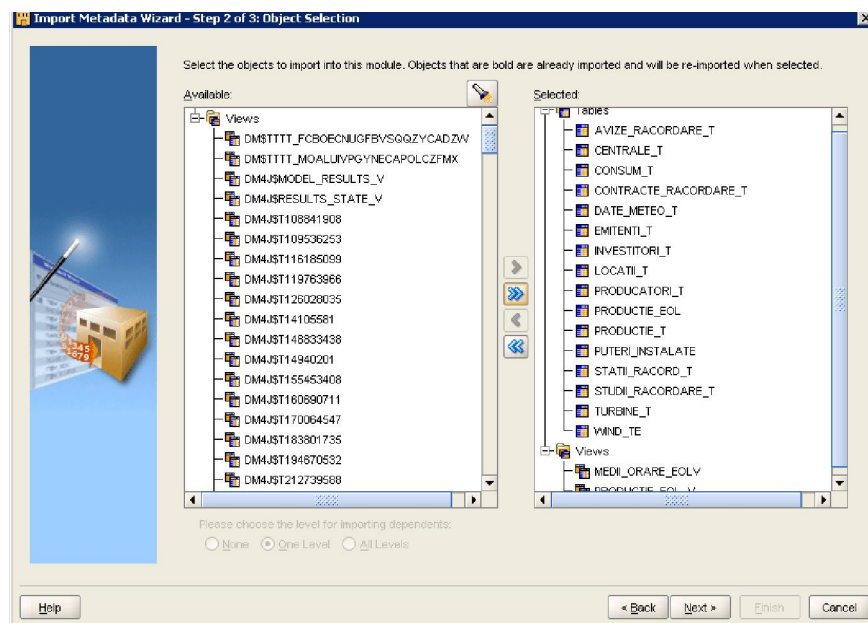


Fig. 3 – Creating the data source module

Source: [1]

Depending on analysis requirements of the decision makers, we have identified the dimension tables, which are the main

structural entities that will be part of the organization and selection of multidimensional data. The dimensions are

organized on several levels, so as to permit typical OLAP operations: rotation, sections, navigation in detail (drill down) and aggregation (drill up / roll up).

For example, DIM\_CENTRALA dimension contains attributes related to wind turbines and wind power stations and is based on a virtual table created on relational tables CENTRALE\_T, STATII\_RACORD\_T and TURBINE\_T:

```
CREATE OR REPLACE VIEW
dim_centrale AS
SELECT s.id_statie_racord,
s.denumire denumire_statie,
s.id_locatie, c.id_centrala,
c.denumire denumire_centrala,
c.id_investitor,
c.putere_instalata PI_Centrala,
c.nr_contract, t.serie_turbina,
t.puterea_instalata PI_turbina,
t.data_punere_fct,
t.id_producator, t.imagine
FROM turbine_t t, centrale_t c,
statii_racord_t s
WHERE t.id_centrala=c.id_centrala
AND
c.id_statie_racord=c.id_statie_racord;
```

In this case, the hierarchical levels in DIM\_CENTRALA dimension are: L\_STATIE - L\_CENTRALA - L\_TURBINA.

Central tables containing measures attributes (metrics) and foreign keys to dimension tables are called data cubes. They usually contain numeric data that can be aggregated and analyzed based on existing levels in dimensions [5].

Particularly important for subsequent analysis and data presentation is CUB\_PRODUCTIE cube that contains metrics related to energy produced by wind turbines. This cube is based on a virtual table created on tables PRODUCTIE\_T and TURBINE\_T:

```
CREATE OR REPLACE VIEW
fact_productie AS
SELECT t.serie_turbina,
t.data_punere_fct, t.data_revizie,
p.data, p.viteza, p.directie,
p.energie_produasa,
p.stare_turbina, t.id_loc,
t.id_producator
FROM productie_t p, turbine_t t
WHERE
p.serie_turbina=t.serie_turbina;
```

The design of data warehouse schema is made using joins between dimension and fact tables within cubes. In our case, a snowflake data warehouse schema model was built (figure 4), because there are joins also between dimensions [1].

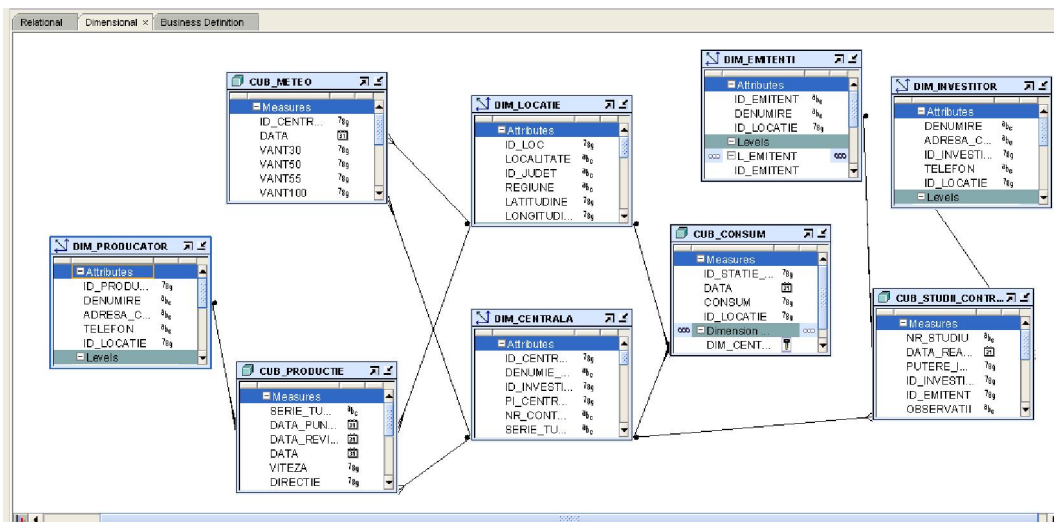


Fig. 4 – Snowflake schema of the data warehouse

Source: [1]

All objects of the data warehouse are stored in database, for each object being created a set of specific PL/SQL

procedures and functions for creating attributes, hierarchical levels of the

dimensions, measures and joins within cubes.

#### 4. Developing the presentation level

The presentation level consists in two major components: interface modules for local Wind Power Plants and interface modules for central management (executives and operative department from central level). Each module has two components: one for current activities like production, consumption, resource allocation, short term prediction, and another component for data analysis based on OLAP model for historical and predictive reporting.

The modules for current management are developed using JDeveloper environment and the modules for analysis are developed using Oracle Business Intelligence Suite.

#### Interface level for the national operator

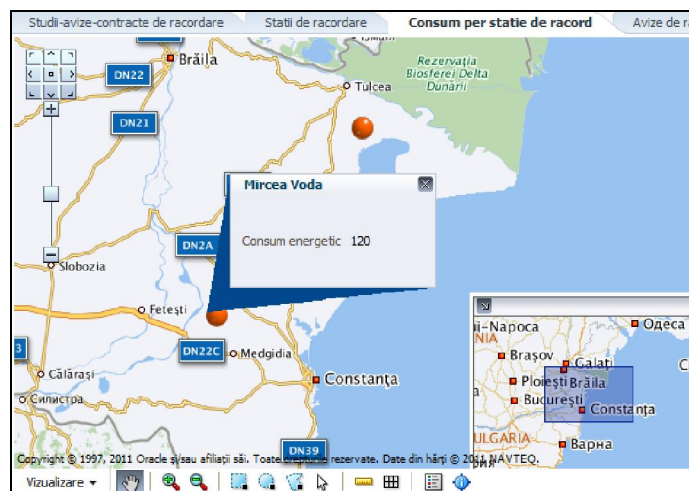
In this step we developed the analyses reports and dashboards for the national

OTS to analyze the renewable production. The application consists in two components: one for current activities and another one for decision support made by a set of analytical reports.

Data from the wind power plants will be presented in different formats for the executives, like: reports, dashboards, pivot tables, charts, and interactive maps.

In the following sections we'll present only some components of the BI modules that allow managers to analyze the evolution of wind generation, consumption and allocation in different periods of time in the selected zones and parks. The interfaces consists of a set of dashboards and reports that presents data in a graphical and intuitive way and available through mobile devices.

Another facility that we've implemented is a geographical representation for an intuitive analysis of renewable resources in different areas and wind parks.



**Fig. 5** - Interactive maps for analyzing WPP production

Source: [1]

The map in figure 4 visually depicts the energy consumption and production for each connected station. When selecting a geographic area and then the station marked the specific indicator is presented in detail.

Figure 5 shows an interactive map for the current studies and notices correlated with the actual contracts between the national OTS and the investors.



The screenshot shows a web application interface with the following data:

Studii Racordare			
NrStudiu	DataRealizare	Putere	Observatii
S11	14.04.2008	90	statia 400/110 kV Tariv
S12	14.04.2008	255	statia 400/110 kV Tariv
S13	14.04.2008	255	statia 400/110 kV Tariv
S14	20.01.2010	147	racordare in statia 110
S15	04.06.2010	168	racord prin statie noua

Avize Racordare			
NrAviz	DataEmitere	DataExpirare	StareAviz
535	18.01.2011	18.07.2011	VALABIL - in curs de react

Contracte Racordare	
NrContract	C100
DataContract	14.04.2008

Fig. 6 – The studies and notices correlated with the actual contracts  
Source: Authors

The results are presented through an OLAP report with navigation facilities between hierarchies (based on 1:n relationship): drill-down, roll-up, slice/dice.

The figure 7 presents the connection stations distributed over the regions having marked the production and the consumption.

The screenshot shows a table of connection stations with the following data:

	Denumire	IdJudet	Latitudine	Longitudine
38	Basarabi	CT	44,179	28,133
31	Medgidia Sud - Rasova	CT	44,179	28,133
32	Pantelimonu (Crucea) Basarabi - G. Ialomitei	CT	44,533	28,233
44	Cernavoda	CT	44,338	28,034
34	Cernavoda Tortomanu	CT	44,338	28,034
33	Cernavoda Mircea Voda-Medg.N.	CT	44,338	28,034
36	Galbiori Harsova	CT	44,492	28,257
41	Limanu Lacu Sarat - Ostrov	CT	43,8	28,533
37	Limanu SN Mangalia	CT	43,8	28,533
39	Jurilovca Sase Martie	TL	44,759	28,875
42	Nistoresti Siriu	CT	44,62	28,379
43	Deleni Cobadin	CT	44,092	28,006
46	Chirnogeni Chirnogeni	CT	43,9	28,233
47	Tichilesti (Horia) Harsova - Topalu	CT	44,602	28,09
49	Baneasa Baneasa	CT	44,07	27,7

Fig. 7 – Analytical report with the connection stations over the geographic regions  
Source: Authors

**Analytical reports at central level**

Based on the data warehouse we've developed a set of analytical reports for executives from the national level in order to observe and analyze the wind power plants connected in the system. For developing we used the Oracle Business Intelligence Discoverer

environment that offers different facilities for multidimensional analyses and graphical elements based on the virtual data warehouse. In this step, by developing the analytical reports for executives, we can validate the data warehouse functionalities and we can establish new requirements and facilities

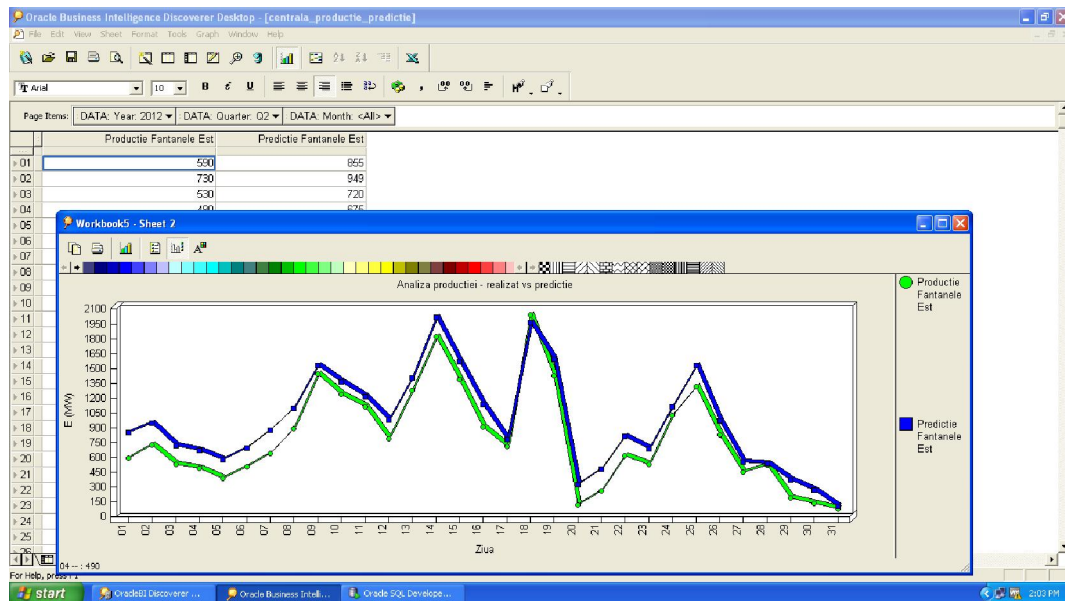
that will be implementing in the next phase.

At this stage, by making useful reports for the executives, the data warehouse functionality is validate, and new requirements and features may be implemented in the next phase of the prototype. We have built several sets of reports for different types of activities pursued in the analysis:

- Reports for grid connection, studies in progress and contracts in progress for WPPs;
- Reports for wind generation and production over time and in different regions;

- Reports for analyzing the consumption in periods of time and different measuring points;
- Reports for analyzing the functioning of national power over different periods of time;
- Reports for wind predictions correlated with wind generation in different WPPs.

For example, in the figure 8 the predictions for wind generation for the current month are represented in the same chart with the actual production and one can observe that the differences recorded are small. The predictions are made by using data mining techniques described in [3].



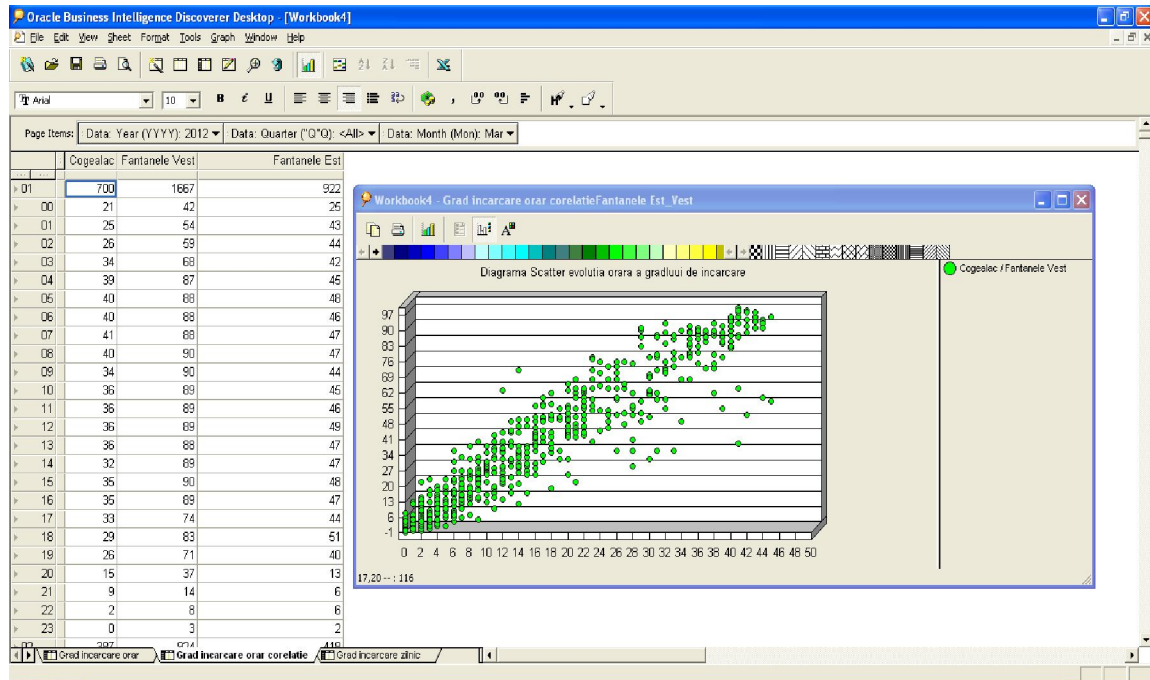
**Fig. 8 - Wind generation predictions vs. actual production**

Source: [1]

### Reports for current production at national level over time

The production is observed and analyzed at national level in correlation and over

regions and meteorological conditions. The analyses are realized for different types of turbines and producers due to noticeable differences.



**Fig. 9** – The correlation between different WPPs

Source: Authors

The report presented in figure 9 allows users to analyze the correlation between hourly productions from WPPs at national level by selecting the quarter, month and day as initial parameters. The reports are flexible, dynamic and allow the user to select the WPP for which the Scatter diagram is presented.

### Conclusions and future work

The current research was conducted within a project won through national competition. In order to achieve rapid validation of data warehouse functionalities, the 2011 phase of the research project has used virtual objects and a ROLAP model (Relational OLAP). Thus, we designed the star / snowflake schema of data warehouse using Oracle BI Discoverer.

But the solution adopted for the prototype implementation is based on a real data warehouse which use multidimensional model (MOLAP), implemented using Oracle Warehouse Builder 11g. In this way the system performance is enhanced, and are allowed in an advanced manner aggregation of measures, storage and

processing cubes, proper data validation and analysis.

The analytical module validates the data warehouse functionalities and offers an intuitive and interactive interface for executive and high-level managers to analyze the major components of WPPs: production, consumption and resource allocation.

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