FORECAST EOLIAN

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Summary

1. Introduction – Effects of wind power plants development on the NES operation

NC TRANSELECTRICA JSC is the Transmission and System Operator for the Romanian National Energy System (NES). Its mission is "ensuring NES functioning in conditions of maximum security and stability, meeting quality standards, developing the national electricity market infrastructure and guaranteeing, at the same time, the regulated access to the electrical transmission network, in conditions of transparency, nondiscrimination and equidistance for all market players."

Using renewable energy sources is a requirement of our times, determined by a series of factors, such as:
- Temperature raise of 0.6±0.2° C in the last century
- CO_2 concentration raise of 31% compared to 1750
- CH_4 concentration raise of 151% compared to 1750 (International Panel on Climate Change, Climate Change 2001: The Scientific Basis Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change)
- Price increase in oil of 680% in the last 20 years
- Price increase in oil of 510% in the last 20 years (???)
- Concerns regarding the possible exhaustion of hydrocarbon resources

Wind power has a globally increasing share among renewable energy sources. This expansion of wind power plants is due to several factors, such as:
- low cost
- almost ubiquitous availability (compared to hydro or geothermal energy)
- technological support
- political support in many countries

The appearance and development of wind power plants represent a new challenge for any system Operator. Expanding the use of alternative energies and particularly of wind energy is a consequence of the European Commission Decision [1] which sets as target, for 2010, that 22,1% of all the energy produced to be from renewable sources. In order for this target to be reached, the energy produced in wind power plants across Europe should be 45-60 GW. In 2003 this goal was increased to 75 GW.

According to Romania's commitments to the European Commission, in 2010 the energy produced from renewable sources should represent 33% of gross domestic consumption, following an increase to 35% until 2015 and to 38% until 2020. By April 2008 in Romania there was a power of 7,7 MW installed in wind farms, but declared intentions of potential producers of wind power installations go beyond 4.000 MW.

Besides its obvious advantages, wind power can raise a series of issues to a system operator, related especially to its intermittent character, energy balancing capabilities having to be ensured at all times [9], which, in many cases involves using energy produced from fossil fuels, with additional costs and increase of pollution (thus reducing the expected impact of wind power use). Another problem that arises is the existence of a capacity in the electricity transmission system to evacuate the energy produced, certain situations requiring the construction of new lines, which leads to an increase in costs.

These problems together with other technical restraints have determined NC TRANSELECTRICA JSC to currently be able to integrate only 1.500 MW in its system.

Under these circumstances, the topic of predicting the power generated in a wind farm, on a range of 48 to 172 hours, becomes one of the most current problems that a system operator has to solve. Therefore, lately, several studies and models have been elaborated globally, to predict on short ranges the speed and direction of wind or of the power produced in wind power plants, bibliography on this topic being extremely extensive [2], [3] , [4], [5], [6], [7], [8], [9], [10], [11] , [12] .

We note that besides the interest shown by System Operators for the short range prediction of wind speed and direction or of power produced in wind farms, a lot more interest in this topic is shown by producers and other participants on the energy markets.

2. Meteorological systems' modeling

Establishing prediction models for wind speed and direction is determined by the fact that, often, the information released by the national weather bureaus is not accurate enough for the specific area where the wind farm is located.

Therefore, lately, several models have been elaborated globally, to predict the speed and direction of wind for a specific point and for ranges of 48 to 172 hours.

2.1. Modeling possibilities

It is already known that in establishing the model for a physical system in order to diagnose and predict its behavior, the following categories are used:
- closed system: a system for which we can identify and measure all the specific features
- opened system: a system for which certain specific parameters cannot be identified or measured

The models that can classify a physical system are separating in:
- Statistical models, resorting to various elements of the theory of signal analysis and on this basis they try to establish connections between "causes" and "effects". They have advantages like not needing a very accurate parameter measurement, permitting a good depiction of evolution over time and not needing to know all the physical parameters, but also disadvantages such as the need for long series of measurements on an extended period of time, therefore being unusable in the first period of model operation.
- Deterministic models start from outlining the system through a series of parameters and mathematical models which make the connection between input and output data. Basically it develops a land surface modeling followed by an algorithm of a fluid flowing over the surface. The model is analyzed with a series of computer applications, finding the answer to multiple combinations of exterior output parameters. The main limitation of this method is the challenge of identifying all the parameters that characterize a system operation with a sufficient degree of certainty. This is why a model like this has to be recalibrated by comparing values "estimated" by the model to values measured on an extended period of time.
- Hybrid models are used especially when we do not have data for certain variables at the time of calculation, these having to be determined by statistical methods, after which they will become

input and output data for a deterministic model.

The prediction of wind speed and direction in a given point is influenced by a series of factors, such as: topography, temperature, atmospheric pressure, values of these parameters in areas neighboring the measuring point, wind speed and direction in neighboring areas etc.

It is obvious that this type of system will eventually be an opened one and using a deterministic model is not generally applicable, since it can only be used in certain regions, thus having a limited degree of generality (see ANEMOS report [5] part. 2.2.1 – Models no longer or never in action).

2.2. Statistical models

Over the time several statistical models of prediction for wind speed and direction have been elaborated. All these models have a limited degree of generality, being adapted to specific conditions for the locations where they were calculated. The results obtained with statistical models have proven to provide a prediction with a low degree of error.

Various calculation methodologies and algorithms have been used for statistical modeling: Kalman filters [15], [16] and [17], recursive algorithms based on quadratic mediums [18], algorithms based on the last values average (on 20 – 30 minute ranges), applied for a medium island [19] , algorithms based on ARMA models [20], autoregressive algorithms that use adaptive models built on fuzzy logic [21], linear adaptive models built on fuzzy logic [22] and [23], autoregressive models and data mining [24] etc.

2.3. Hybrid models

One of the most famous hybrid models is Zephyr – Prediktor used in the ANEMOS program. This model was implemented in Spain, Scotland, USA (Texas), Ireland, Denmark, Benelux and Japan. The Prediktor system uses a NWP (Numerical Weather Prediction Model) to determine wind speed and direction, after which it transforms this information in data for wind speed and direction in the point of interest. In the end this data is transformed in generated energy using a set of power curves. The results obtained are corrected with the help of a statistical module; the correction can be made both before and after transformation of wind speed and direction in power. As we can see the two basic elements are the NWP and the statistical module. In the Denmark implementation DMI Weather forecasting system [13] was used as a NWP; this uses the HIRLAM 6.3 application, which modulates in the guise of a network with 0.15° respectively

0.05° resolution and 40 vertical levels. This kind of applications needs to run on a NEC SX6 supercomputer and covers Northern Europe and the British Islands.

Another system that uses hybrid modeling is AWPPS (ARMINES Wind Power Prediction System) [14] , developed at Ecole des Mines de Paris. The AWPPS system was implemented in 35 wind farms in Denmark, Germany, Greece, Ireland, Spain, Portugal and Great Britain placed in different field conditions. The operating principle of the system is shown in the picture below.

The AWPPS system has as input data the information provided by a NWP (ex: HIRLAM, ALADIN, SKIRON) and from online measurements.
The Power Prediction module is built with adaptive fuzzy neural networks. The AWWPS system accuracy is of 10 % - 15 % for the next 48 hour prediction and of 8 % - 10 % for the next 24 hour prediction.

An NWP project worth mentioning is the ALADIN project (Aire Limitée Adaptation dynamique Développement InterNational) initiated in 1990 by Meteo-France. At this project adhered 16 countries over the time and one of them is Romania, represented by INMH. The project was developed with contributions from all members and totaled a labor volume of over 250 people/year and 26 PhD theses. Currently INMH makes predictions using the ALADIN model.

- Modeling weather systems as opened systems, using statistical and hybrid models
- Factors that influence wind speed and direction (pressure, temperature, topography, etc.)
- Modeling weather systems at a large scale / on small areas. Linear models, spatial models. ALADIN model

3. TELETRANS proposal for a pilot system of wind speed and direction prediction in a wind farm area

TELETRANS is the informatics and telecommunications subsidiary of NC TRANSELECTRICA JSC. In this quality, it operates a communications network on optical fiber of over 6000 km, with national coverage, a network that can represent the element of support for a system of predicting wind speed and direction.

3.1. Defining a mathematical model for the pilot system

The mathematical model proposed for the pilot system will be a hybrid model.

Three components will be taken into account:

- Long term evolution tendency
  - Will use a deterministic model that will assess a general orientation of the parameter evolution
  - Will use a polynomial in the time variable
  - It is determined using the smallest squares method
- Periodic variation (seasonal)
  - Deterministic model – phenomenon repeatability parameter evolution
  - Used model – the main period highlighted and the medium sample values corresponding to the period
  - It is determined using the Wittacker-Robinson method
- Random variation
  - Non-deterministic model associated to disturbances that affect the evolution of the parameter
  - Used model – white noise filtered
  - It is determined using the Levinson-Durbin algorithm

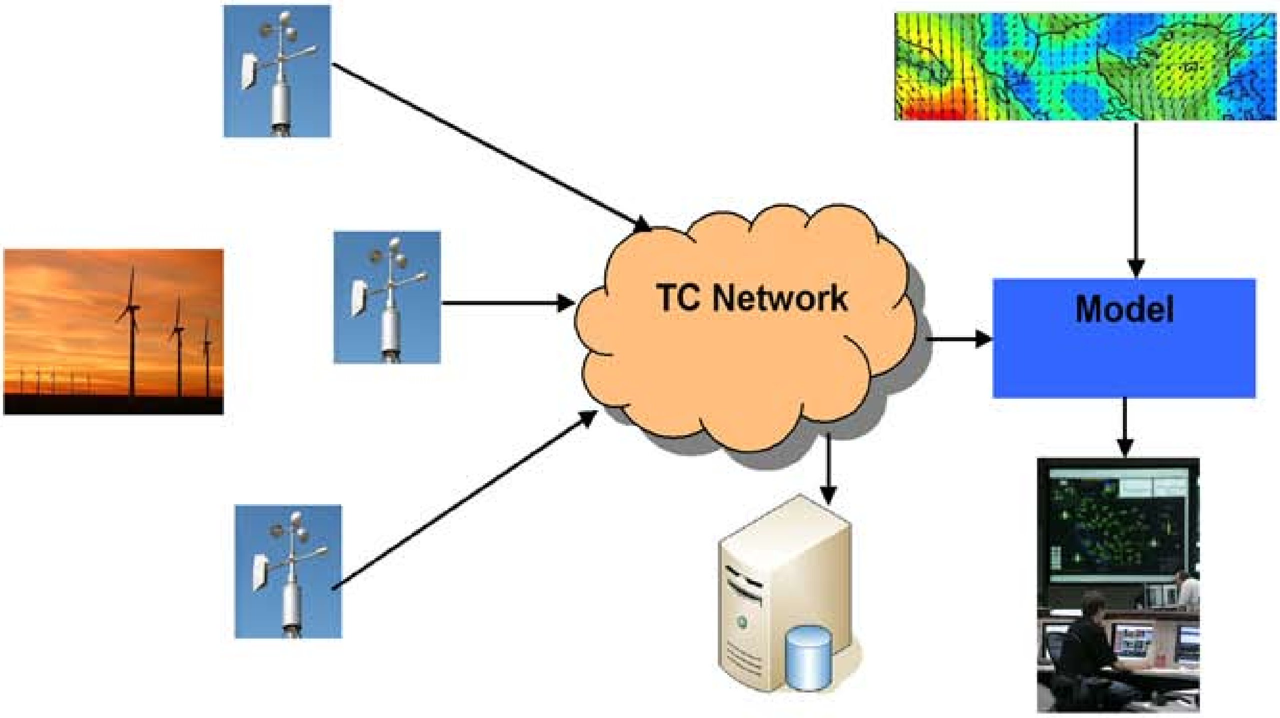
The resulted model will be a 2k input and one output system: the 2k inputs are the atmospheric pressure and the wind vector in k points, while the output is the wind vector in the calculation point.

Choosing the number of system inputs will depend on:

- The distance between the calculation point and the measurement point of input data
- The topography of the area to be modeled, the possibility of gathering data from a matrix that can cover all neighboring areas

3.2. Structure of the proposed pilot system

The proposed pilot system will be consisted of: data gathering installations, telecommunications network and computer equipments that will model the system.



The data gathering installations will be set up in TRANSELECTRICA sites, benefiting from both collocation conditions and access to the telecom network. These installations are characterized by:
- Energetic autonomy (they use energy produced by the monitored wind)
- Storage capacity for long term recordings (at least 1 year)
- Low cost

The mathematical model will be implemented on servers installed at the National Energy Dispatch.

The first step will be gathering data on a time period and calculating parameters for the mathematical model.

After that we will proceed to model calibration:

- o Value prediction at the calculation point
- o Calculation of prediction error and prediction error dispersion
- o Model recalibration by recalculating transfer and weight functions or by introducing the reduction/correction factors

The system will become functional after calibration.

As the system will expand and the coverage area will become larger, the prediction error will decrease even more.

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