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EVALUATION OF WIND ENERGY POTENTIAL IN DOBRUDJA

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Key words: wind energy, Dobrudja, turbines, potential

Abstract. The purpose of this article is to cover a gap in the research and literature and it provides specialists in various fields of wind engineering accurate data on wind characteristics and the wind potential of the atmospheric boundary layer above Dobrudja. This presentation aims to bring an original contribution to a more accurate and complete assessment of wind characteristics and to a more precise estimation of the wind potential in Dobrudja. According to the results obtained and the processing of the measurements, we can draw the conclusion that Dobrudja is an area characterized by a high wind energy potential, which represents an available energy source ready to be harnessed by the implementation of wind turbines.

Introduction

Currently, the concern regarding the use of the wind potential in Dobrudja is connected to the 1995 study (at ICEMENERG). The purpose of this study was to find a solution for the building of an aero-electric power station at the Black Sea, with an installed capacity of 20000 MW, with a detailed analysis for the north jetty of the Constanta Harbor. Measured data must exist in the very location in order to establish a wind energy power station, and since no such direct data existed, the value of the investment was estimated at over 30 million US dollars. Thus, beginning with 1996, meteorological data began to be collected with specialized translators located at 28 m above the sea level, on the White Lighthouse of the harbor protective jetty. The measurement of the wind parameters is done with NRG-USA translators corresponding to the European regulations. For wind speed, the anemometer used has a measurement domain of 0…44.7 m/s. Wind direction was determined with a vane with potentiometer-type sensor which measures the direction on the domain 0...360°.

The data acquired with a frequency of 8 Hz are first processed directly on the field data-logger based on a specific program which collects data every 10 minutes, a sampling duration considered representative by the countries with wind energy experience in order to characterize the energy exploitable wind. Within this primary

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statistical processing, apart from obtaining means, the maximum and minimum instantaneous values are selected from the interval, the maximum accelerations and decelerations (of blasts) are calculated, and the turbulence, as an important characteristic of energy wind, defined by the square mean deviation of the instantaneous speeds compared to the mean of the respective string of speeds. The values of the 10-minute temporal samples are the basis for the determination of the daily, weekly and monthly average values.

Based on the studies elaborated at national level, the Black Sea continental shelf is the first interest area from the wind energy standpoint, while the littoral is third after the mountainous zone.

The conclusion that can be drawn is that the realistic wind energy potential installed on Romanian territory is approximately 28000 MW, 13200 of which being in the Black Sea continental shelf. The total energy that can be obtained is approximately 63 TWh/year, of which, approximately 80% will be harnessed from the continental shelf and the littoral zone of Dobrudja.

This paper has evaluated the wind potential for weather stations representative of Dobrudja, off-shore Gloria weather station, and across the Dobrudja (Saint George, Constanta, Mangalia, Medgidia, Adamclisi), based on specific methods for estimating the potential measurements and models of wind speed probability distribution.

1. Material and method

For this study, we analyzed not only the speed and direction of the wind from the weather stations in Dobrudja, between 1965 and 2005 (Figure 1), but also the resulting data using the ANEMOMETER M - 4838. There have been two essential methods used in order to estimate the aeolian potential: the measurement method and the probabilistic pattern method.

Figure 1. Location of weather stations in Dobrudja

Wind monitoring was performed at St. George, Constanta, Mangalia, Gloria, Adamclisi and Medgidia stations for the period 1965-2005. This period is sufficient for assessing wind potential. Data about wind speed and structure for a period of at least one year are required for the choice of facilities locations.

The wind potential of the site could be determined by two methods. The first method is based on measurements made during a specific period (1965-2005), at the above mentioned weather stations. The second method is based on Rayleigh's probabilistic model that allows rapid assessment of wind potential if the multiannual average wind speed is known.

Calculation of wind potential was realized for different wind directions at six sites, using the following calculation formula:

– *Using the measurement based method:*

$$\varepsilon = \sum_{i=1}^{m} \frac{\rho \cdot [U_i(10)]^3 \cdot n_{Ui}}{2 \cdot N} \qquad \textbf{(1)}$$

– *Using Rayleigh's probabilistic model:*

$$\varepsilon = \frac{6}{\pi}\left(\frac{1}{2} \cdot \rho_{an} \cdot U^3_{man}(10)\right) \qquad \textbf{(2)}$$

where : **ε** - wind potential (W/m^2) , **ρ -** air density; **U_{man} (10)-** annual average wind speed the standard height of 10 m [m/s], n_{Ui} **-** is the number of data within the range *(U, U_{i+1})* length ΔU with Ui **= (i-1)** Δ_U, and **N** (the total number of measurements) **=** $\sum_{i=1}^{m} n_i$, **ρ_{an} -** annual average air density [kg/m^3].

To describe the profile of the average wind speed at different heights, **U(z)**, the surface of the sea and different directions, was applied power law or the law of Davenport, which is the mathematical expression **U(z)=U(10)·[U(z)/U(10)]$^\alpha$**, where **α** is an exponent that depends on the nature of the terrain roughness. The formula for potential wind farm in Dobrudja, where the roughness is small and where the exponent to Davenport is about 0.16, at different heights and in different directions of the wind, is the following:

$$U(z) = U(10) \cdot \left(\frac{z}{10}\right)^{\alpha} \qquad \textbf{(3)}$$

Taking into account the fact that:

$$\mathbf{U(z)/U(10)=(z/10)^{0,16}} \qquad \textbf{(4)}$$

the result is the expression:

$$\boldsymbol{\varepsilon}\ \mathbf{(z)= \boldsymbol{\varepsilon}(10) \cdot (z/10)^{0,48}} \qquad \textbf{(5)}$$

where:

ε(z) - is wind potential at height **z**(W/m^2)**, ε(10) -** wind potential at standard height calculated from **U/(10)** (W/m^2), **z -** conventional height of the surface of the ground (sea) (m), **0,48** - roughness coefficient calculated according to the land (or sea).

Wind potential values were determined both by a statistical method based on measurements taken over a period of forty years (1965-2005) and by a method based on probabilistic model Reyleigh distribution. Sometimes, for convenience, wind potential determined by the two methods was called, in a simplified manner, "Measured wind potential" and “Calculated wind potential”.

Obviously, wind potential assessment based on measurements made on a sufficiently long duration is more accurate than assessment by Rayleigh's probabilistic method. However, calculations were performed with this second probabilistic method just to check whether the Rayleigh model leads to potential values close to the values determined based on measurements and so, if the probabilistic method may be used with a suitable approximation in the absence of measurements for other time intervals.

2. Results and discussion

2.1. Measurement based method. Average annual values of wind potential were obtained in the main weather stations in Dobrudja using the measurement based method. Depending on the values of potential, curves of wind potential were determined regardless of wind direction and for different heights.

The most deficient areas in terms of wind potentials are those in which atmospheric calm frequency is high - at the Adamclisi station, where calm frequency was 21.5%, wind potential varies between 210 W/m^2 at 10 m and only 1050 W/m^2 at the top of the boundary atmospheric layer; at the Medgidia station, in the central-southern Dobrudja, it varies between 200 and 1040 W/m^2, where atmospheric calm registered an average of 26.8% - the highest in Dobrudja - during the 1965-2005 period, Figure 2.

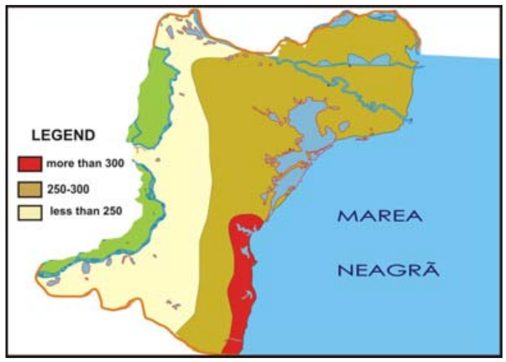

Figure 2. Territorial distribution of the wind potential (W / m²) computed on the basis of measurements regardless of wind direction at 10m height in Dobrudja (1965-2005)

3.2. Rayleigh Method. The Rayleigh Method leads to potential values close to the values determined based on measurements and therefore, in the absence of measurements for other time intervals, the probabilistic method can be used with a suitable approximation.

The values resulting from the calculations were drawn in graphs representing changes in wind potential.

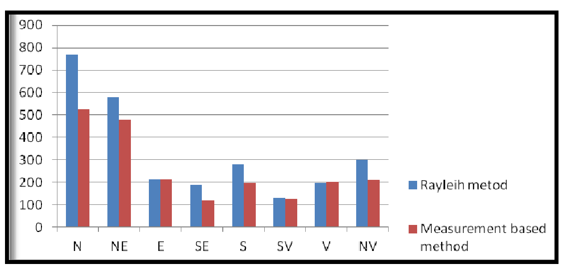

Figure 3. Wind potential (W/m^2)at St. George Station, applying the Rayleigh and measurement methods (1965-2005) with different wind directions and heights

Thus, it appears that the largest wind potential (regardless of wind direction or height) in Dobrudja is still in the coastal area (in which there are a series of differences). To achieve the intended purpose of making a comparative analysis between the two methods double histograms had to be plotted against wind potential values calculated for cardinal directions and inter-cardinal of wind, both on the basis of measurements of a period of five years and on Rayleigh's probabilistic model for Saint George (Figure 3), Constanta (Figure 4), Mangalia (Figure 5), Medgidia (Figure 6) and Adamclisi (Figure 7).

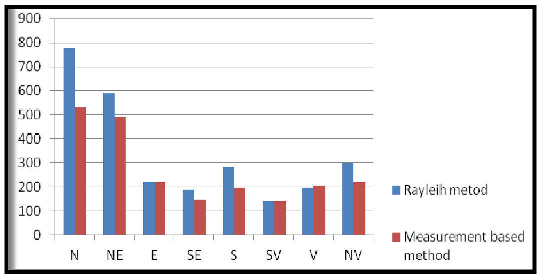

Figure 4. Wind potential at Constanta Station, applying the Rayleigh and measurement methods (1965- 2005) with different wind directions and heights

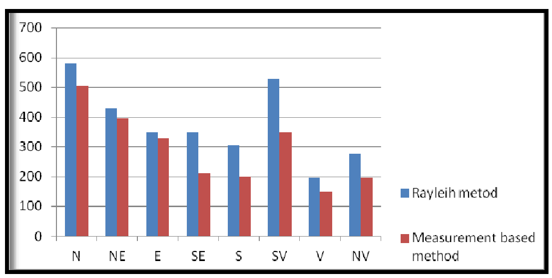

Figure 5. Wind potential at Mangalia Station, applying the Rayleigh and measurement methods (1965- 2005) with different wind directions and heights

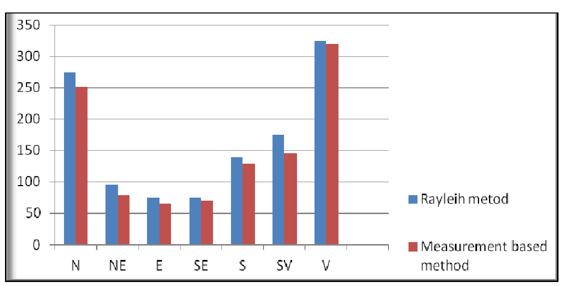

Figure 6. Wind potential at Medgidia weather station, applying the Rayleigh and measurement methods (1965- 2005) with different wind directions and heights

Estimation of wind energy converted within Dobrudja

• The energy produced by a wind plant is a key parameter in the economic assessment of these facilities.

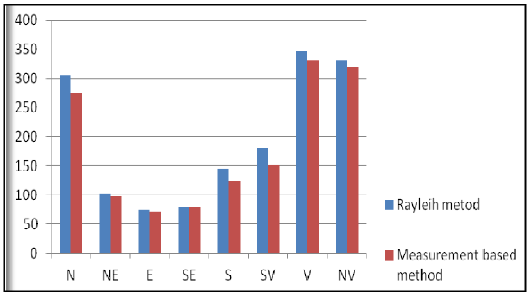

Figure 7. Wind potential at Adamclisi Station, applying the Rayleigh and measurement methods (1965-2005) with different wind directions and heights

• Annual energy converted by a wind plant can thus be calculated using the expression:

$$\mathbf{E_{T,an} = Cp \cdot A \cdot (\sum_{i=1}^{m} \rho \cdot U_i^3 \ / 2 \cdot n_{Ui}/N) \cdot T} \qquad \textbf{(6)}$$

• Given that the term

$$\sum_{i=1}^{m} \rho \cdot U_i^3 \ / 2 \cdot n_{Ui}/N \qquad \textbf{(7)}$$

is an expression of potential wind-based measurements, converted to annual energy expression is obtained:

$$\mathbf{E_{T,an} = C_p \cdot A \cdot \varepsilon \cdot T \cdot 10^{-3}, (kWh)} \quad \textbf{(8)}$$

where: C_p is power coefficient, A = cross-sectional area of the wind turbine active (m^2), T = during the assessment (1 year = 8760 hours).

• Choosing the appropriate type of turbine is due to the peculiarities of wind turbines with horizontal axis and vertical axis. Each type of wind turbine has some advantages and disadvantages.

• Converted wind energy has been calculated annually for the two types of turbines, in Dobrudja and the coastal zone (the area with the highest wind potential of the territory considered), regardless of wind direction, 10 m height.

• Wind potential values (W/m^2) and converted energy (kWh/year) for a wind plant with vertical axis and with different diameters at a height of 10 m, regardless of wind direction, are shown in figure 8.

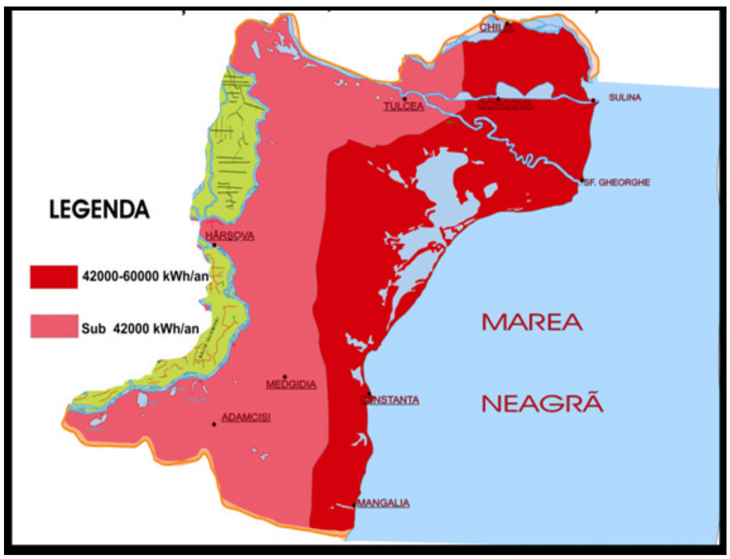

Figure 8. The distribution of converted energy (kwh/year) for installation with vertical axis wind regardless of wind direction at 10 m height in Dobrudja (1965-2005)

• Wind potential values (W/m^2) and converted energy (kWh/year) for a wind plant with horizontal shaft with different diameters at a height of 10 m, regardless of wind direction, are shown in figure 9 .

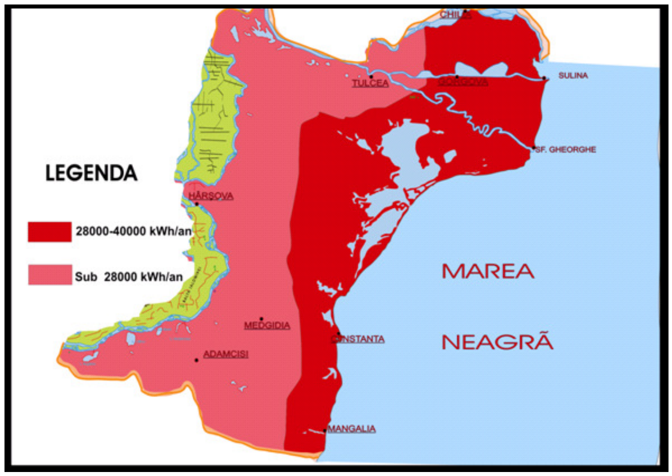

Figure 9. The distribution of converted energy (kwh/year) for a horizontal axis wind installation regardless of wind direction at 10 m height in Dobrudja (1965-2005)

Conclusions

The purpose of this article is to cover a gap in the research and literature and it provides specialists in various fields of wind engineering accurate data on wind characteristics and the wind potential of the atmospheric boundary layer above Dobrudja.

By this study, we intend to bring an original contribution to a more accurate and complete assessment of wind characteristics and to a more precise estimation of the wind potential in Dobrudja. According to the results obtained and the processing of the measurements, we can draw the conclusion that Dobrudja is an area characterized by a high wind energy potential, which represents an available energy source ready to be harnessed by the implementation of wind turbines.

By comparing the wind potential values obtained in this work with wind potential values of other countries belonging to the European Union that have the potential Dobrudja as good as at many other places in Europe.

• The analysis of synoptic situations leading Dobrudja wind potential, the following conclusions can be drawn:

- Azores anticyclone has the highest frequency, with relatively constant intensity of pressure (1020 ... 1026 mb.), compared with the Siberian having high intensity values only in winter (1035 mbar) and very low in summer (999 mb.), and negative values of gradients barrel in the summer months.

- Depression Icelandic has higher intensity than depressions Mediterranean Action Centre, hence the latter are more active weather development in the Black Sea.

- Black Sea surface wind regimen is influenced by the movement of air masses from the atmospheric boundary layer, the land-sea interaction, the absence or presence of natural obstacles, the continental tropical air entering and rarely comes from central Asia, and extremely hot and dry air of African origin which causes the heat and the Romanian seaside. Tropical Marine Air Atlantic is home and enters the Black Sea during the current prevalence of the southwest. Penetration of such air in winter is associated with a warming of the Romanian Black Sea coast. Arctic air spread is caused by the movement north along the meridian, but this spread has a small share as arctic air cannot always get to the Black Sea.

- Intensifying wind specific short summer months, July-August, when the wind speed has values within the range value 14 ... 18 m/s.

- The most accurate method of calculation that can be used to assess wind potential for different wind directions and heights at the coastal stations Saint George, Constanta, Mangalia Adamclisi, Medgidia and Gloria, and the entire Romanian Black Sea coast, is clearly the measurement based method.

High values recorded in Dobrudja wind potential for a wind north or north-western sector. Although these plants are not polluting, and the energy generated by them does not affect the environment, there are however protests as these actions could affect the Danube Delta ecosystem. Ornithologists argue that lands leased by investors are habitat to over 372 species of protected birds, but wintering area of more than 1 million migratory birds that could be affected by the installation of such turbines.

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