AEOLIAN POTENTIAL ESTIMATION IN AREAS WITH COMPLEX OROGRAPHY

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Abstract

This paper presents some of the preliminary results of the anemometrical measurements campaign on the hill areas. These areas could benefit from the installation of some small dimension wind generators.

The analysis refers to areas known as "marginal", that is, they have an energetic density and medium speed that do not really justify, from an economic point of view, the investment in a high dimension wind station. (according to a vague classification, the areas considered "poor" have less than 200W/m^2 and the "marginal" areas have between 200 and 300W/m^2).

The final decision will be determined by the wind statistic analysis from the areas of this type, with the help of Weibull distribution and some other parameters designated to quantify the zone turbulence. It will be demonstrated how one of the most interesting characteristic of this area type, that is the high energetic density of the speed distribution "heads" is significant and not only the relatively small value of the medium speed.

Key words: wind, statistic analysis, Weibull,aeolian, potential,complex orography

INTRODUCTION

Conventionally, not long ago, they were considered recommended areas for setting the wind turbines:

- on the seaside;
- small orographical influence;
- reduced land rugosity.

Nowadays other areas have started being analyzed and considered to have "wind source":

- the inside of the continent
- the high orographical influence
- the high rugosity of the land.

MATERIAL AND METHODS

The vertical profile of the wind: The gradient wind reduces its speed close to the soil, fact that can be described by a logarithmic law. In order to apply this law, one has to know the two parameters:

- u^* is the shear velocity that includes the effect of the *friction force*;
- z_0 that represents the soil type *(rugosity)*
- k is Von Karman constant equal to 0,4.

$$\bar{U}(z) = \frac{u^*}{k} \cdot \left[\ln\left(\frac{z}{z_0}\right)\right]$$

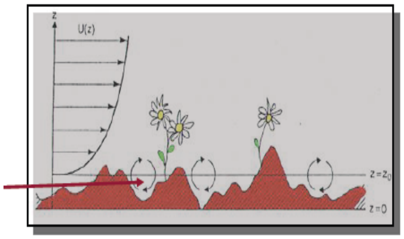


Figure 1. The Vertical Profile of Wind Velocity

The orographic acceleration (Speed up): When an incident air flow meets a relief form, the speed distribution on the vertical axe slightly modifies itself. Among the changes of the speed vertical profile we mention: the wind that initiates downhill slows down on the relief slope, then starts to accelerate and reaches the maximum speed around the top of the slope, where the curvature degree of the profile is the lowest:

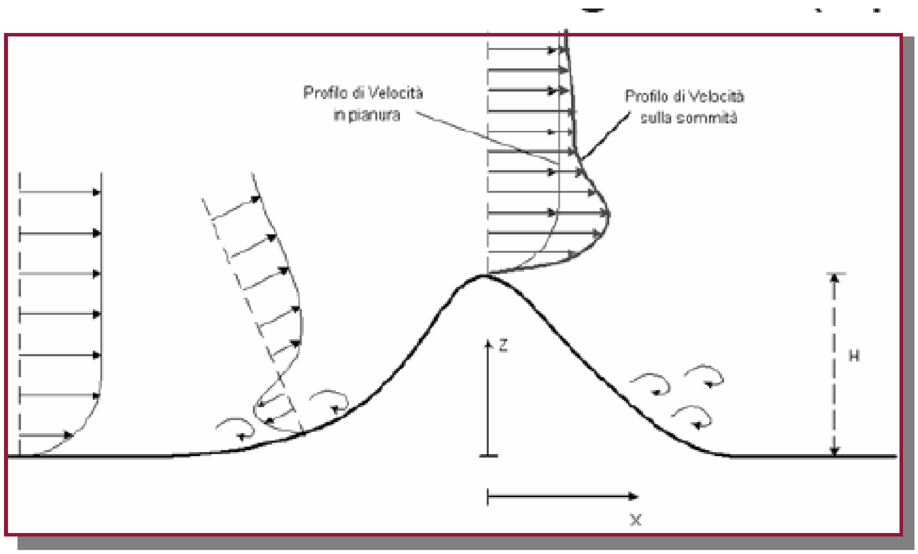


Figure 2. The „speed up" effect due to the zone orography

The wind speed is a vector with a modulus and direction that modify themselves very fast in time, and because of that, the three components that characterize the speed $v_x(t)$, $v_y(t)$, $v_z(t)$ will be treated as random variables. The only components of interest in the wind industry are $v_x(t)$, $v_y(t)$. Doppler anemometrical devices are being used, devices that are capable to register with a very high sample frequency these components: wind speed and direction.

Because the fixed wind stations that are strongly influenced by the wind direction are somehow out of date, this paper focuses on the variation of speed modulus in time. The distribution of the Weibull probabilities (Wind statistics) is the one that better describes the wind variable.

$$p(u) = \frac{k}{c}\left(\frac{u}{c}\right)^{k-1} \cdot e^{-\left(\frac{u}{c}\right)^{k}}$$

This type of distribution is characterized by two parameters: standard mean and deviation, specifically referring to U_{10}

- c is a scale factor, biunivocal bound to the medium speed. To determine this factor we use :

$$U = c \cdot \Gamma\left(1 + \frac{1}{k}\right)$$

- where Γ represents the Euler function $\Gamma(x) = \int_0^\infty e^{-t} \cdot t^{x-1} dt$

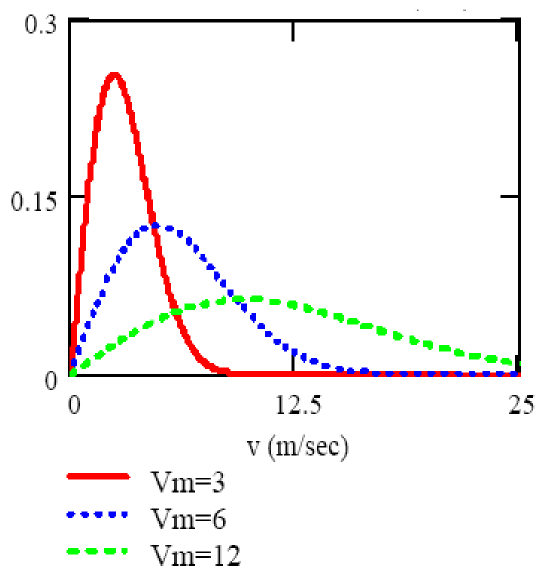
From a physical point of view, the dimensions of the c factor are those of a speed.

- k is a shape factor, adimensional, that modifies the distribution symmetry, values very close to 1 represent distributions strongly asymmetrical, while values higher than $2 \leq k \leq 3$ determine symmetrical distributions, very similar to the Gaussian ones. In a particular case, for k=2, the Raileigh distribution is achieved, and this can be used for evaluations when only the medium speed is known.

The advantage of a statistical approach is that it allows successive evaluations of productivity, independently from the gross measurements data, but in the same time it condenses very well the statistical properties of the temporal series.

This Weibull distribution intends first to determine the mean, then the variation and finally the energetic density (proportional to a third power wind speed). We are obviously interested in the medium wind speed, but in this paper we intend to go into details as regards the dispersion influence and the way it is interpreted. The most important is the standard deviation σ, which measures in fact the turbulence (or the turbulence intensity “TI”).

Figure3. The figure proves the influence of the two parameters c and k for a temporal series of data:



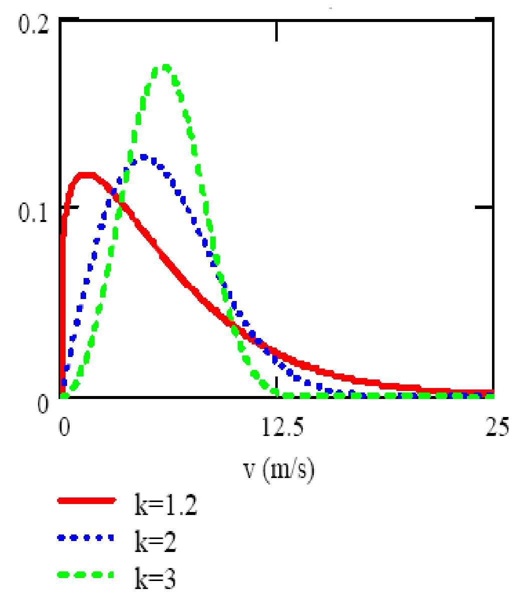


Fig 3.a)Variation of medium speed for k=2

Fig 3.b) Variation of k parameter, for an average speed equal to 6m/s

From a N temporal series given by the speed $u_i\left(i=\overline{1,N}\right)$:

$$TI=\frac{\sigma_u}{U}$$

- U is the medium speed;

- σ_u is the standard deviation;

From a physical point of view, the turbulence derives from the dispersion of the wind kinetic energy into thermal energy during the process of formation and destruction of the small whirlwinds of very small dimension. A precise description of these data is adequate to the sample (at least 1Hz), i.e. a high sensitivity of the used anemometer. The turbulence intensity expressed in percentage, is a fundamental characteristic as long as this project depends on it. The experience has proved that turbulence in its turn depends on the medium speed within the interval taken into account.

Starting from the land structure, the turbulence will be higher when:

- The zone topography is complex; it has hill sides with steep slopes, valleys, peaks, etc.
- The land has a “rugged” covering. Taking into account the air fluid dynamics, the rugosity is determined by the human buildings, trees, forests, isolated buildings, etc. The wind industry defined these classes of rugosity which start from a calm sea, fields, steppes till forests and cities as indicated in the following figure:

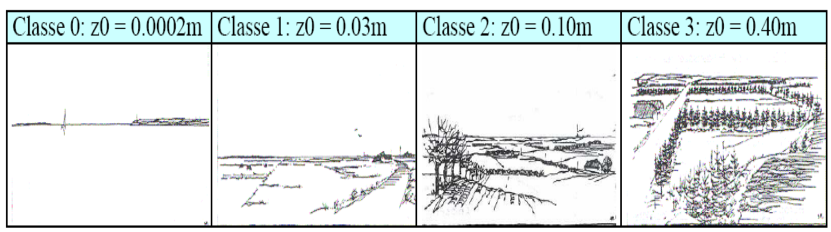


Figure 4. Classes of rugosity

The turbulence intensity TI may be sufficient, but in fact it is only a small part of information from the temporal series of data. We mention only the methods used without going into mathematical details:

1. The autocorrelation. The autocorrelation function studies the temporal aspect of the situation answering to: “how it is correlated the speed v(t) at a time t>, being given speed $v(t_0)$ at a time t_0”.
2. The duration/ time specific to turbulence: the duration when the speed variations are correlated, meaning there is an evident “memory” effect of the fluctuation. (< 10sec) The specific turbulence Duration/Time: the duration when the speed variations are well correlated, meaning the moment when there is an obvious variability “memory” effect. (<10sec) The specific duration is easy to find by multiplying time with the medium speed, and from a

physical point of view it represents the medium size of the whirlwinds.

3. The density function of the spectral power, the"turbulence spectrum" (PSD power spectral density). The spectral density function proves how much the energetic content differs from the wind frequencies.

On a temporal scale of observations, very different phenomena can be highlighted: from the atmospheric fronts of over 3-4 days (synoptic peak), to day/night cycle around cities, coasts, valleys (diurnal peak), till the micro whirlwinds of only some centimetres (turbulent peak). An interesting characteristic of the "wind spectrum" is the so-called "spectral gap" which consists of an obvious energy gap in the range from T=10min. and T=2h. (see fig. 5)

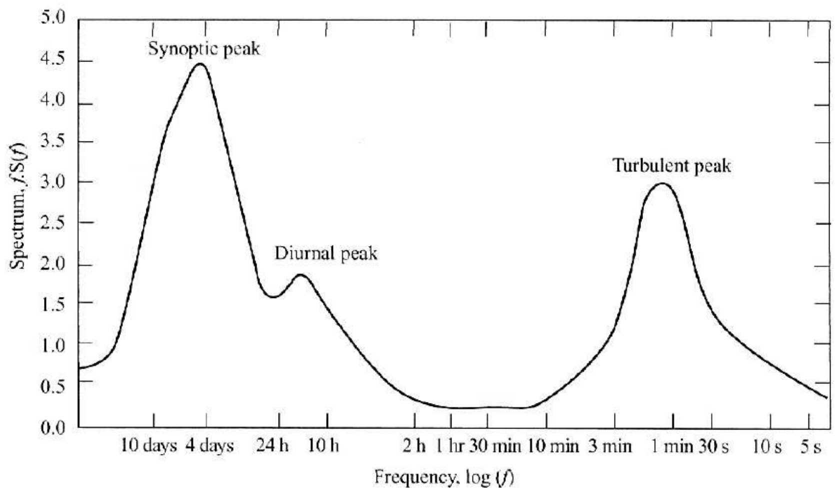


Figure 5. Temporal scale of observations

Comparison between the multi-annual monthly average wind speeds measured at Oradea Meteorological Station and anemometric measurements in the hilly area that borders Oradea in the north – north-eastern part, made during the elaboration of this thesis in November, December 2007 and January 2008.

These measurements must last for 18 months; it is a short but sufficient period of time, because there is the Airport meteorological station which is in the possession of some historical data, to whom the measured data can be correlated. Nevertheless, some clear tendencies can be already observed:

- The gross measured data "tell only the history" of the local wind, underlying the episodes with strong wind and atmospheric calmness.

- The histogram shows the measured data, the red curve proves the Weibull distribution which reproduces accurately both the medium speed and the energetic density of the measured data.

The turbulences’ intensity variation towards v

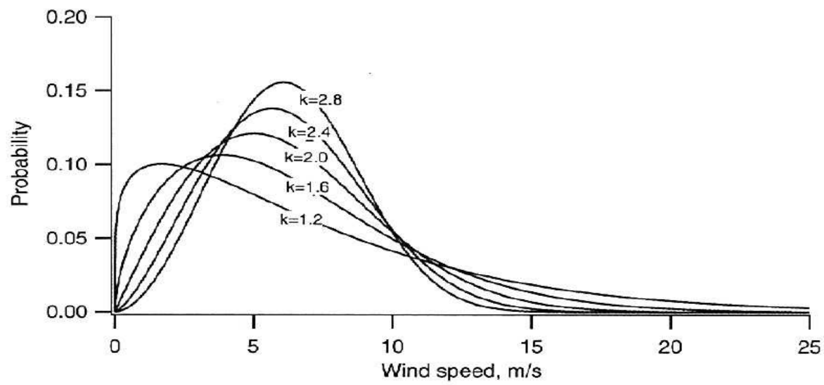


Figura 8. The effect of the k factor variation for a speed of u<8m/s

The following effects which influence immediately the wind characteristics of the area can be observed from analyzing this graphic.

RESULTS AND DISCUSSION

At the same medium speed	k<2	k>2
Speed dispersion around medium value	It increases: a smaller value of k makes the distribution flater and more asymmetrical, causing a higher speed dispersion, and as a consequence, it makes the higher speeds more “likely”	It decreases: a higher value of k indicates a distribution that aims at a symmetric Gaussian, with a more and more narrower peak (so, wind speeds f, constantly around the average)
High speeds (> than the average)	Become more likely	Become less likely
Low speeds (< than the average)	Become less likely	Become less likely
Energetic density	increases	decreases
The committed error using only the medium speed for evaluations	increases	decreases
A traditional wind turbine (of a nominal speed equal to twice the zone medium speed	Produces more energy a year and is liable to higher charges	Produces less energy a year

CONCLUSIONS:

1. The possibilities of the energetic revaluation of the orographic zone have been presented
2. The possibilities of the local turbulence exploitation and not only of the wind medium speed have been underlined
3. In order to take advantage of these zone particularities, small, sensitive and strong turbines need to be used.

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