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Cristian Paul Chioncel, Petru Chioncel, Nicoleta Gillich, Thomas Nierhoff

Overview of Classic and Modern Wind Measurement Techniques, Basis of Wind Project Development

For an accurate prediction of the production for windpowerplants and to chose the rigth location for such investments, the main information are given through long time and punctual windmeasurements. That's why the accuracy of a proper wind resource assesment and the rigth data management give the necesary information about the wind shear, turbulance and variability (temporal and spatial). The paper presents the main windmeasurement technics to identify the vertical wind profil, wind speed, wind rose and the time distribution of those parameters.

Keywords: *wind measurement, anemometer, LIDAR*

1. Introduction

For the calculation of the delivered energy, information about the long term (at least 10 years) wind charcteristics are requiered because the fluctation in energy supply, in different wind years, depending on local conditions, can make approximately +/- 20% of the long years average value [2]. That means that for the assessment of the wind measurement data of shorter times, on long-term measurement data, possible nearby meteorological stations, must be used.

2. Wind data representation

After the current wind speed comes with the third Power in the Power of the wind, the recording of the long-term averages data for the calculation of the Energy, not sufficient.

The usual method to extract the frequency of different wind speeds is given by the *classification*. The measured velocity values are divided in classes of 1 m/s and represented as frequency distribution, figure 1.

Those information, obtained through measurement technics, are analytically described by the Weibull distribution, described by the shape parameter k and scalnig factor A, [1]. The shape parameter *k* describes the shape of the Weibull curve and usually takes a value between 1 and 3. In case of the Rayleigh distribution, the form parameter takes a fixed value of 2. The Rayleigh distribution is used to calculate the energy output, when, for the site, exist only the average value for wind speed and not the measured frequency distribution, figure 2.

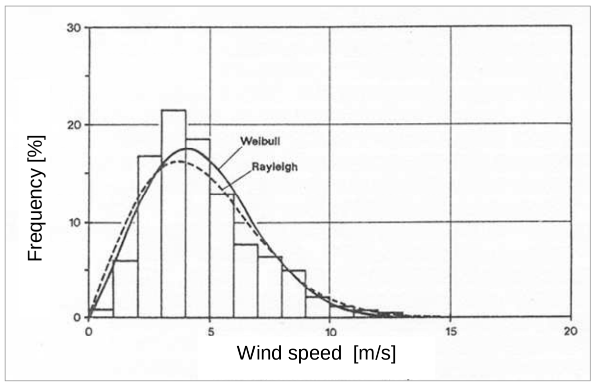


Figure 1. Example of a frequency distribution

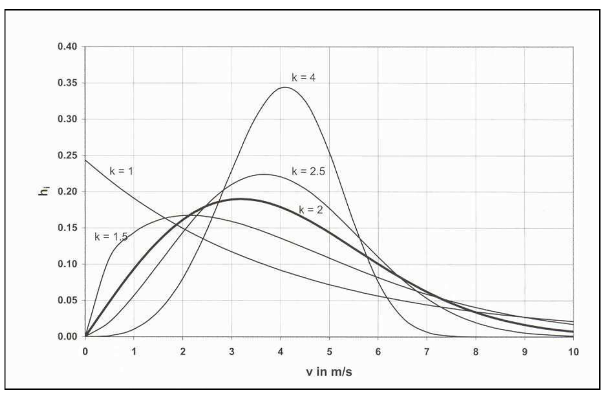


Figure 2. Wind speed distribution based on the Weibull function for a mean wind speed V=4 m/s; k=2 Rayleigh distribution

For the energetic use of the wind, the wind direction is also extreme important, because the position of the windturbines on site have to consider the preferably wind-downs too. The wind direction can be totally changed by local, regional and seasonal factors, figure 3.

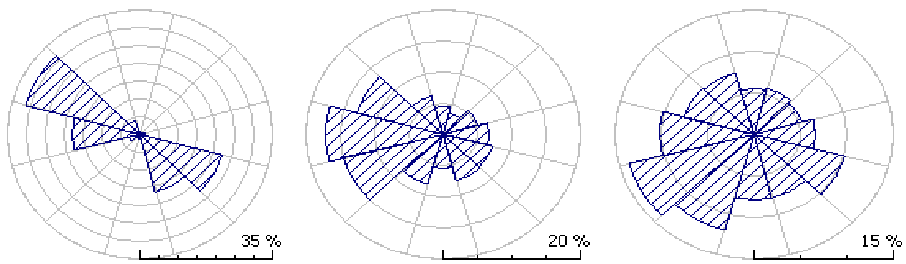


Figure 3. Examples of wind direction distributions

3. Wind measurement equipment

For the measurement of the wind speed, different sensors can be used: cup star anemometer, ultrasonic anemometer, etc..F or short-term measurements and the measurement of specific wind characteristics (e.g. vertical wind profile, wind shear, turbulence ...), special equipment can also be used: LIDAR (LIght Detection and Ranging), SODAR (Sound Detection and Ranging), 3-D ultrasonic anemometer.

The measurement of wind speeds is usually done using a cup anemometer, has a vertical axis and three cups which, capture the wind. The number of revolutions per minute is registered electronically. Normally, the anemometer is fitted with a wind vane to detect the wind direction. Those anemoters are usauly attached on a measuring mast, at different heights, figure 4. If the wind speed is known in two heights, so, the wind speed can be in principle calculated for any other height [5]

$$\frac{v_1}{v_2} = \frac{\ln\left(\frac{h_1}{z_0}\right)}{\ln\left(\frac{h_2}{z_0}\right)}, \qquad (1)$$

where h_1 – height one [m], h_2 – height two in [m], v_1 – wind speed in h_1, v_2 – wind speed in h_2, z0 – roughness [m].

The cup anemometer have the advantage to be robust, easy to maintain but is not able to measure other wind components beside the horizontal on, to proper register moment wind intensity and can be overshadowed by the attached strings of the wind measurement mast.

The sonic anemometer, figure 5, operates on the principle of measuring the exact length of time that a high frequency sound pulse (typically 100 kHz) is needed to put a certain distance between two points back. The way along and across the wind direction is measured.

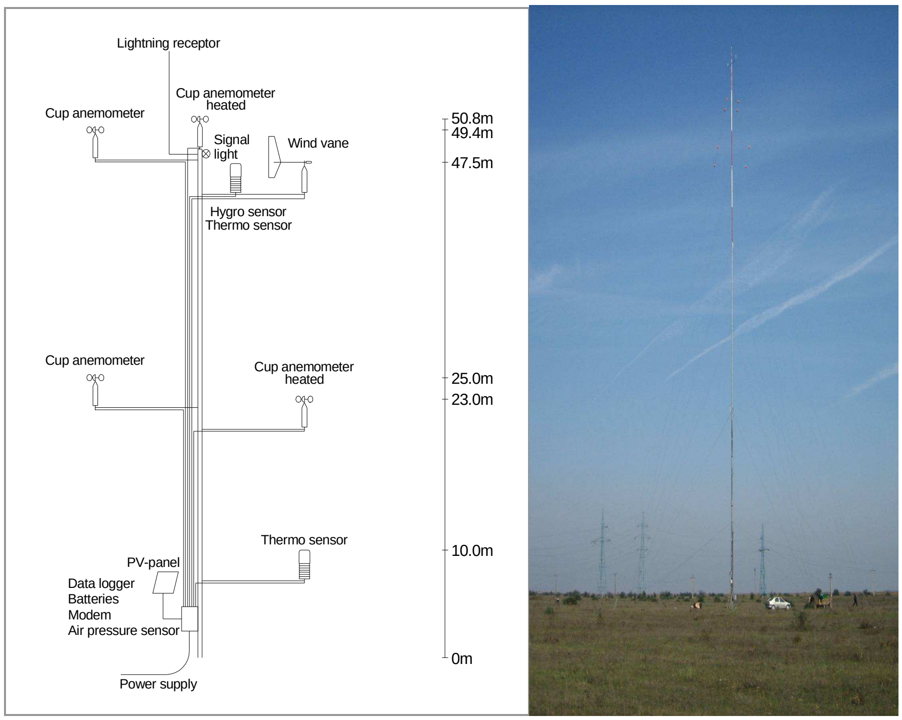


Figure 4. Scheme of a 50m high wind measuring mast

The principle of the sonic anemometer base on measuring the time a sound wave needs to cross certain, fix distance. This will be expressed through the relationship between the time difference Δt and the wind speed V_d is [5]:

$$\Delta t = \frac{2d}{a^2} v_d , \qquad (2)$$

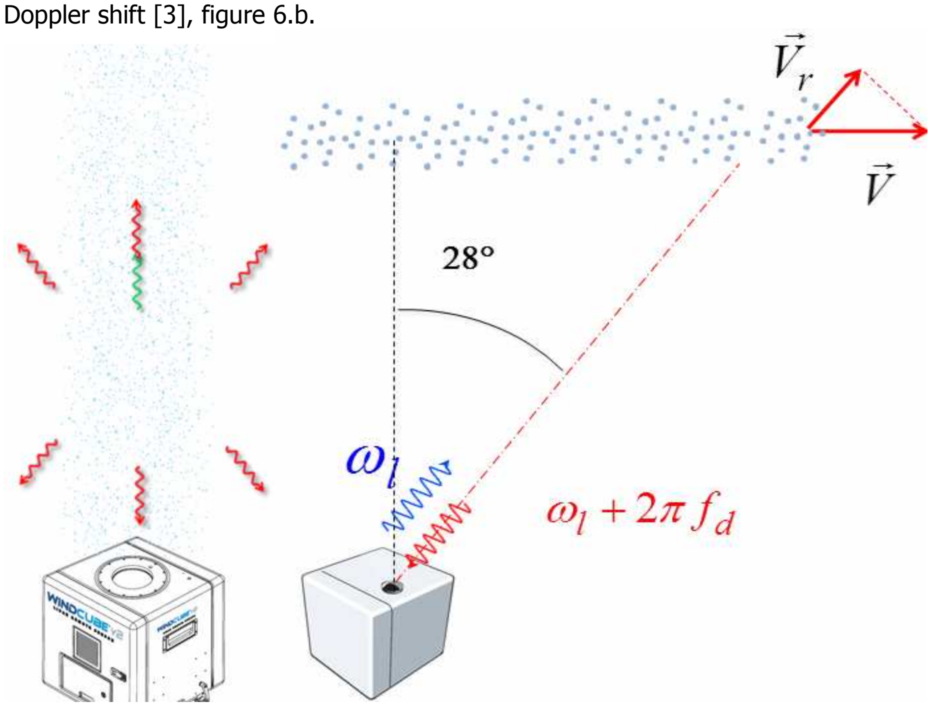
where *a* - speed of sound waves; *d* – length of the distance between terminals

Figure 5. Sonic anemometer

The LIDAR (Light Detection And Ranging) has the advantage [6] to: offer a remote sensing of wind characteristics based on the diffusion of sound waves; simultaneous measurement of wind speed at different heights between 20 m and 150 m with a height resolution of 5 m; simultaneous measurement of three-dimensional wind speed; no flow control by mast, rope or fasteners; wind speed averaged over a volume of several cubic meters provides an advantage over a punctual measurement with anemometer.

A short light pulse is emitted from the base station. This light has to be back-scatter through the present aerosols in air, figure 6.a. The probed altitude is linearly linked to pulse flight delay.

Light frequency is shifted by Doppler effect due to aerosols speed, where the aerosols speed is equal with the wind speed. The Doppler shift is 1.3 MHz for a 1m/s radial wind speed and only the radial wind component is affected by the Doppler shift [3], figure 6.b.



a. b.

Figure 6. LIDAR wind measurement principle

This method allows the 3D wind vector construction [4], from the following measurement hypothesis: the existence of a homogeneous wind at given altitude and constant wind speed during four lines of sight measurements. The wind vector projection, figure 7, gives:

$$
\begin{aligned}
Vr_1 &= X\sin(\alpha)+z\cos(\alpha)\\
Vr_2 &= Y\sin(\alpha)+Z\cos(\alpha)\\
Vr_3 &= -X\sin(\alpha)+Z\cos(\alpha)\\
Vr_4 &= -Y\sin(\alpha)+Z\cos(\alpha)
\end{aligned}
\quad . \tag{3}
$$

This system, (3), leads to:

$$
\begin{aligned}
X &= \frac{Vr_1 - Vr_3}{2\sin(\alpha)}\\
Y &= \frac{Vr_2 - Vr_4}{2\sin(\alpha)}\\
Z &= \frac{Vr_1 + Vr_2 + Vr_3 + Vr_4}{4\cos(\alpha)}
\end{aligned}
\quad . \tag{4}
$$

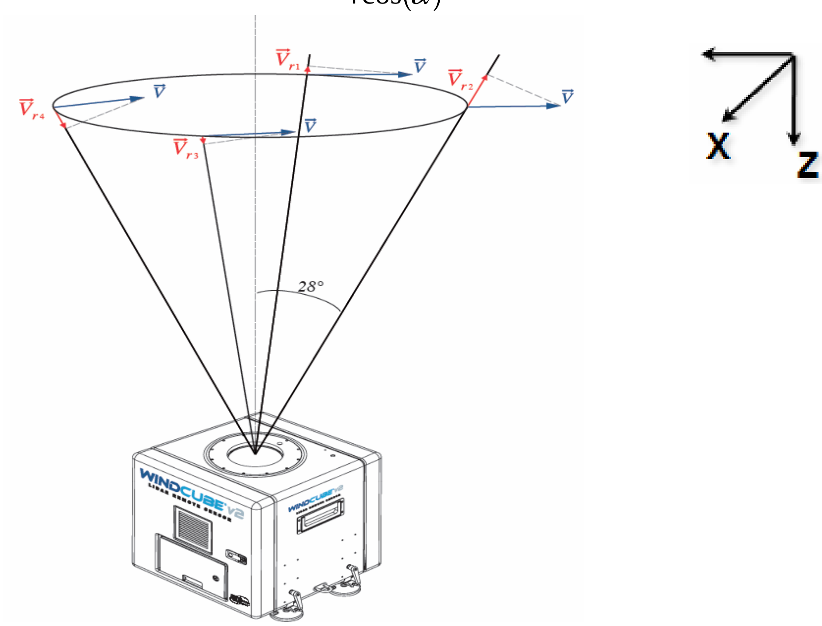


Figure 7. 3D wind vector construction

The LIDAR measurements technique ensures the following performance [7]: a min – max range from 40 to 400m, speed range from 0 to 60m/s, data sampling rate 1s and results in 12 measurement heights. The steps described before, can be represented in global LIDAR measurement algoritm, as shown in figure 8.

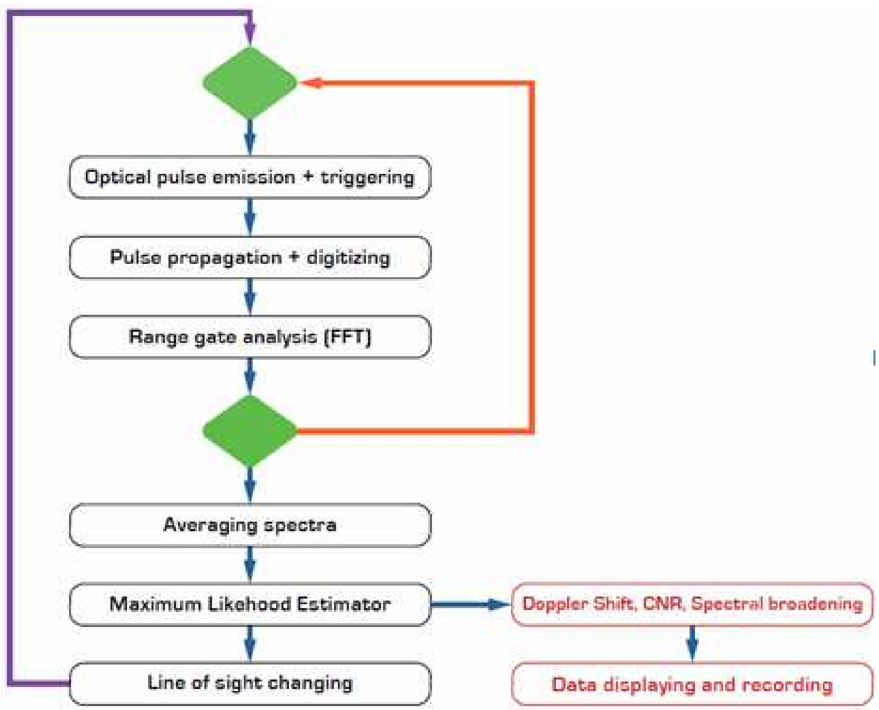


Figure 8. Global measurement algorithm

4. Conclusion

In developing a wind farm, the first and main important step is to make good resource assessment, modeling, at a local level, the wind farm layout, for the given wind conditions. For this purpose the main condition is to have good, long term, wind measurements. That information has to provide a robust prediction of the expected long-term energy production, over the wind farm's lifetime. For project sites where the surface has a high roughness, local winds with a high grade of turbulences or the plane to use wind turbines with a high hub height, require for an accurate forecasts, the use of an LIDAR measurement.

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Addresses:

- Lect. Dr. Eng. Cristian Paul Chioncel, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, c.chioncel@uem.ro
- Prof. Dr. Eng. Petru Chioncel, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, p.chioncel@uem.ro
- Prof. Dr. Eng. Nicoleta Gillich, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, n.gillich@uem.ro
- Dipl.Ing Thomas Nierhoff, Fachhochschule Gelsenkirchen, D-45877 Gelsenkirchen, thomas.nierhoff@fh-gelsenkirchen.de