# Criteria and Instruments for Choosing a Wind Turbine

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***Abstract:*** *Wind energy is becoming one of the most widely used renewable energy sources in Romania as well. In order for production to be efficient and implicitly profitable, wind turbines are usually arranged in wind farms. The main purpose of the paper is to present intelligent criteria and tools for designing wind turbines. In the present study, the following are pointed out as topics of interest: the shading of the wind given by an obstacle, the height of the turbine hub, the distance between the obstacle and the turbine, the roughness class of the turbine location, the height and width of the obstacle and the porosity of the obstacle. These elements help to determine the variation of the wind front, the power of the wind captured by the turbines and the calculation of the energy captured. The results obtained using calculation programs are: wind speeds are in the range of 5-10 m / s in the predominant direction S-SE (between $270^0$-$330^0$) and V-NV (between $150^0$-$210^0$); power density function; Weibull distribution for wind speed; turbine power curve; Wind turbulence in the turbine area; power coefficient depending on wind speed; The amount of energy that the wind transfers to the rotor; Wind frequency curve; speed insurance curve. Finally, by using the modelling tools in Math Lab Simulink, the random speed distributions were obtained, which can be analyzed and then provided to obtain a maximum power, and consequently a maximum amount of energy.*

***Keywords:*** *Tool, wind, turbine, parameter, shade, obstacle, power, energy*

## 1. Introduction

Wind energy is becoming one of the most widely used renewable energy sources in Romania as well. In order for production to be efficient and implicitly profitable, wind turbines are usually arranged in wind farms. It should be noted that a wind speed of a minimum of 3m/s and a maximum of 25 m/s is required for the operation of a wind turbine. In addition, at start-up, a wind turbine consumes about 750 kW. The service life of a turbine is 20 years [1].
In order for a wind turbine to be installed in a particular location, certain conditions must be met:

• the intensity of the wind during a year to allow a constant production;

• signalling the presence of access roads in the area;

• signalling the presence in the area of high voltage transmission lines;

• no environmental restrictions (protected areas);

• the location of the wind turbine to support its mass;

• the site should be free of loads.

From wind studies [2] it can view wind intensity maps depending on the chosen location. These points clearly show the points where the wind intensity is maximum, points where the wind turbines will be installed later. Because wind turbines have a considerable height (¬150 m with a blade) and must withstand the maximum wind speeds recorded at the site, buried concrete foundations are built to fix them.
Turbines do not require a human operator. They are monitored from a dispatcher through internet connections and SCADA programs - Supervisory Control And Data Acquisition - Surveillance, control and data acquisition program.

## 2. Material and methods

### 2.1. The influence of obstacles on the speed picked up by the turbine

In the present study are pointed out as topics of interest: the shading of the wind given by an obstacle, the height of the turbine hub, the distance between the obstacle and the turbine, the roughness class of the turbine location, the height and width of the obstacle and the porosity of the obstacle. These elements help to determine the variation of the wind front, the power of the wind captured by the turbines and the calculation of the energy captured.

### 2.2. Assumptions and calculation elements

#### *2.2.1. Calculation hypotheses*

- the presence of the obstacle on the wind can extend up to 2..3 times the height of the obstacle at a certain distance.
-- distance between obstacle and turbine- On very rough terrain the effect of obstacles can be measurable up to 20 km distance from the obstacle.

- roughness of the terrain between the obstacle and the wind turbine - The terrain with low roughness will allow the wind that passes outside the obstacle to mix more easily after the obstacle, so that the shade of the wind is relatively less important.

- obstacle height-The higher the obstacle, the greater its influence on the wind front.

- obstacle width - The obstacle calculation model works on the assumption that the obstacles are infinitely long and that they are placed at right angles (perpendicular) to the wind direction. For practical reasons, we assume that we are investigating the horizon around the wind turbine in twelve 30-degree sections (in 10 percent steps).

- the porosity of an obstacle is a percentage indication of how open an obstacle is, i.e. how easily the wind can pass through it (A building obviously has zero porosity. A group of buildings with a certain space between them and have a porosity equal to (open space area) divided by (total area of both buildings and the open space between them, seen from the wind turbine).

#### *2.2.2. Experimental research*

#### *2.2.2.1. Input data*

- the location of the turbine and the height of the turbine tower (Figure 1);

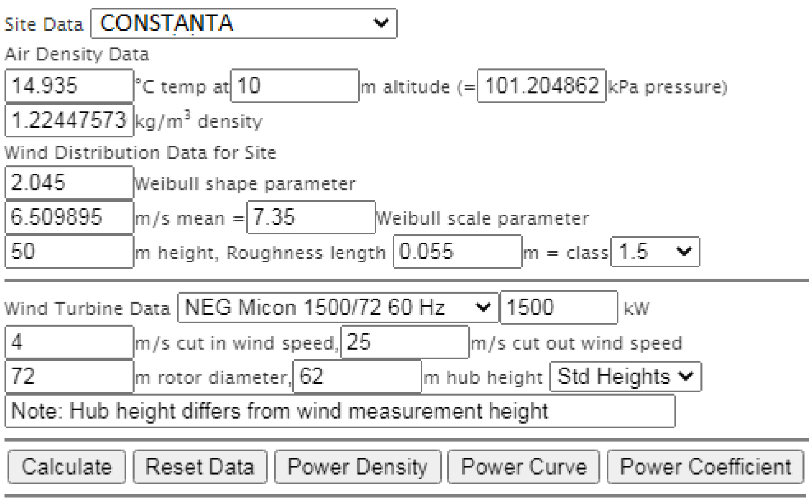


**Fig. 1.** Chosen study location

- wind speed in the given location (wind rose) [3] (Figure 2, Figure 3);

- obstacles in the area (height, width, roughness, porosity).

Therefore, using a virtual computer to simulate the case study, we introduce the option for the study location and data related to altitude, temperature, air density, pressure, turbine type, wind speed and we will get information about power, energy, power curve of the turbine depending on the wattage speed, power coefficient (Figure 1).

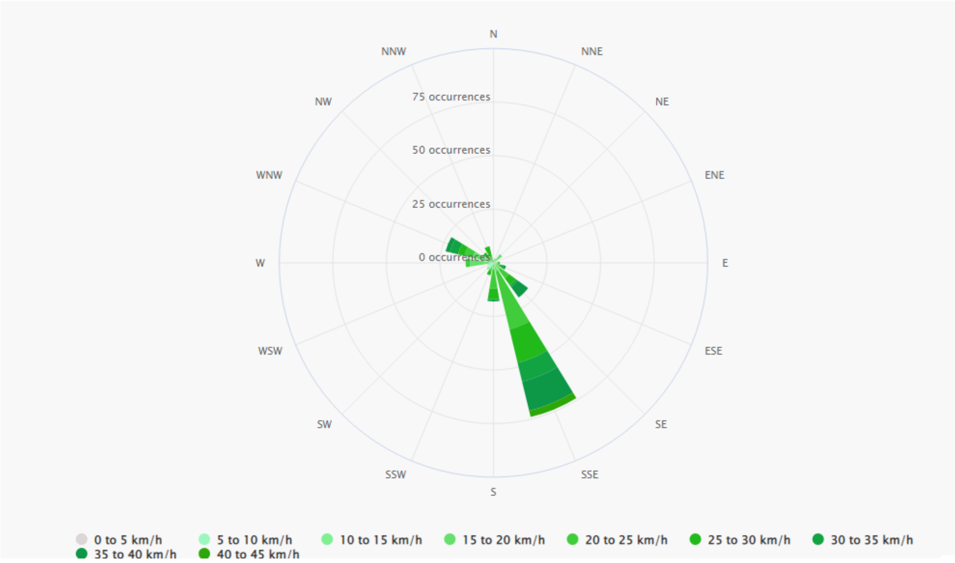


**Fig. 2.** Wind rose for the study location

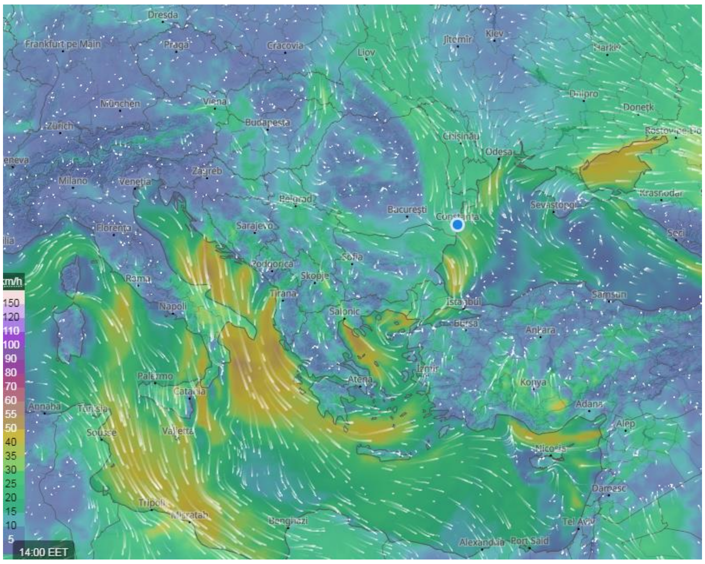


**Fig. 3.** Wind map for the study location

It is observed that most values for wind speed are in the range of 5-10 m / s in the predominant direction S-SE (between $270^0$-$330^0$) and V-NV (between $150^0$-$210^0$).

### *2.2.2.2. Results*

The results were obtained using a virtual computer [2]:

- *porosity of obstacles*;

Using a calculation program [2], results are obtained for the porosity of the obstacles [4] (Figure 4) depending on the height of the turbine tower (Figure 5):

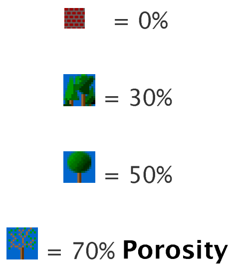


**Fig. 4.** Obstacle porosity representation code [4]

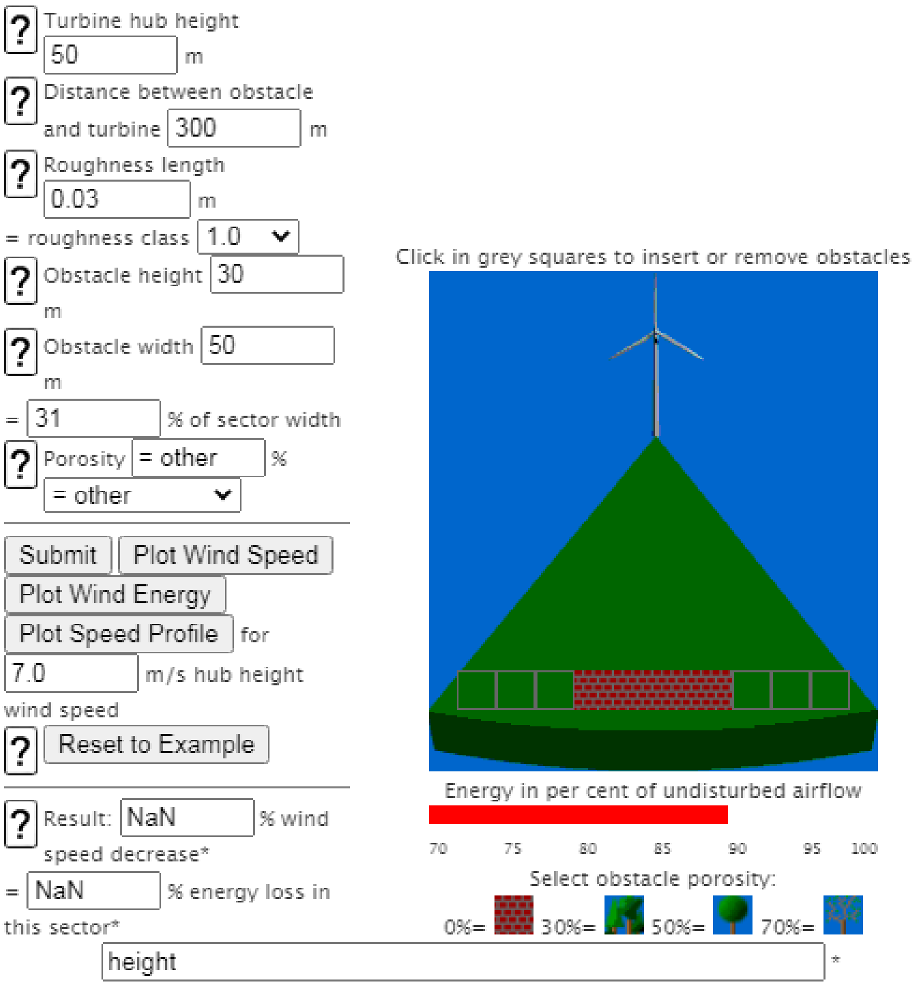


**Fig. 5.** Obstacle porosity [4]

To estimate the potential in the study location, measurements were made by purchasing 2000 data for wind speed and direction for the reference elevation of 10 m and using the Simulink MathLab program. The speed variations that were later used to assess the turbine power were estimated.

- *wind power*

Wind power– it can be calculated the power density function (Figure 6) [5]:

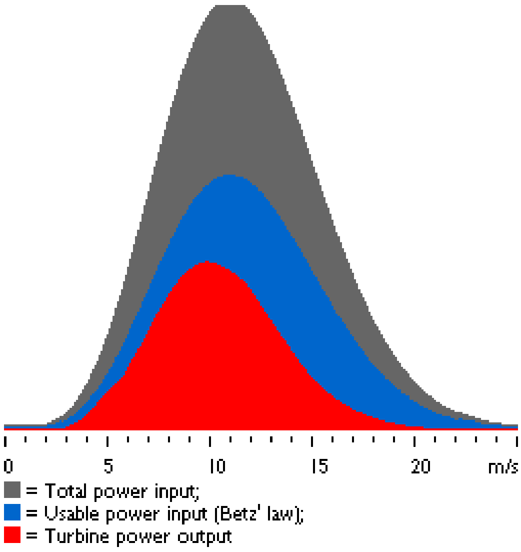


**Fig. 6.** Wind power variation [5]

- *Weibull wind speed distribution* (Figure 7) [6]

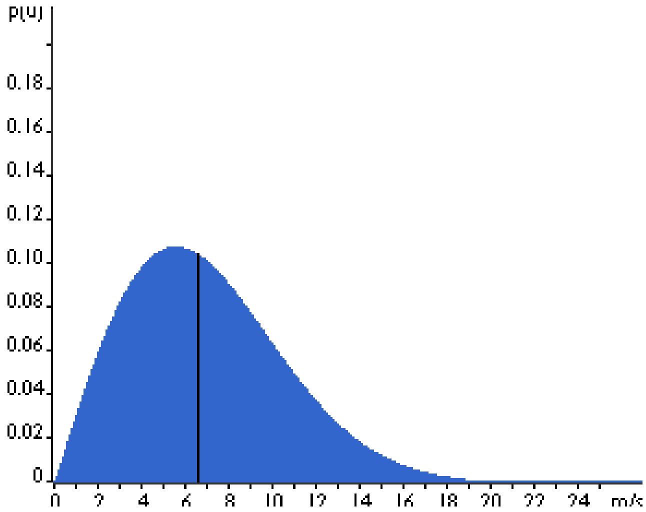


**Fig. 7.** Weibull distribution for wind speed [6]

- *turbine power curve* (Figure 8, Figure 9)

We can calculate the turbine power using the formula:

$$P = \frac{1}{2}\rho \cdot \mathrm{v}^3 \cdot \pi r^2 \quad (1)$$

Where

P - the power of the wind measured in W;

$\rho$ - the density of dry air = 1.225 [kg/m$^3$], at $p_0$- atmospheric pressure at sea level at 15° C;

v = the velocity of the wind [m/s];

$\pi$ = 3.1415926535...;

r = the radius (a half of the diameter of the rotor [m]).

| Site Power Input Results | | | Turbine Power output Results | | |
|---|---|---|---|---|---|
| Power input* | 347 | W/m2 rotor area | Power output* | 110 | W/m2 rotor area |
| Max. power input at* | 10.6 | m/s | Energy output* | 964 | kWh/m2/year |
| Mean hub ht wind speed* | 6.7 | m/s | Energy output* | 3925989 | kWh/year |
| | | | Capacity factor* | 30 | per cent |

Wind Turbine Power Curve

| m/s | kW | m/s | kW | m/s | kW |
|---|---|---|---|---|---|
| 1 | 0 | 11 | 1285 | 21 | 1500 |
| 2 | 0 | 12 | 1426 | 22 | 1500 |
| 3 | 0 | 13 | 1451 | 23 | 1500 |
| 4 | 0 | 14 | 1483 | 24 | 1500 |
| 5 | 74 | 15 | 1500 | 25 | 1500 |
| 6 | 202 | 16 | 1500 | 26 | 0 |
| 7 | 356 | 17 | 1500 | 27 | 0 |
| 8 | 576 | 18 | 1500 | 28 | 0 |
| 9 | 808 | 19 | 1500 | 29 | 0 |
| 10 | 1058 | 20 | 1500 | 30 | 0 |

**Fig. 8.** Numerical values for wind turbine power curve

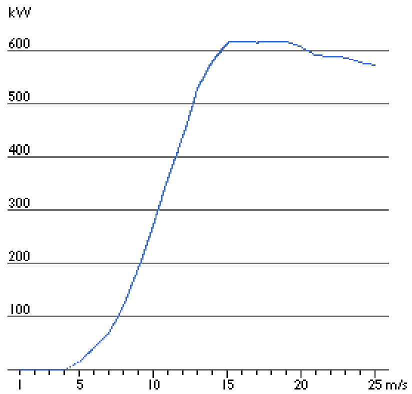


**Fig. 9.** Wind turbine power curve [7]

- *turbulence* (Figure 10) - decreases the possibility of efficiently using wind energy for a wind turbine. It also requires more wind turbine rupture and wear voltage:

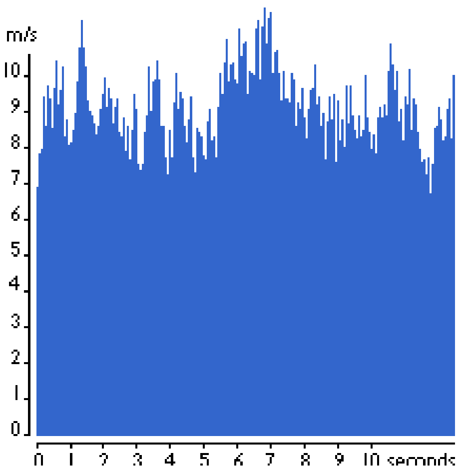


**Fig. 10.** Wind turbulence in the turbine area

- *the power coefficient* depending on the wind speed has the value 44 (Figure 11):

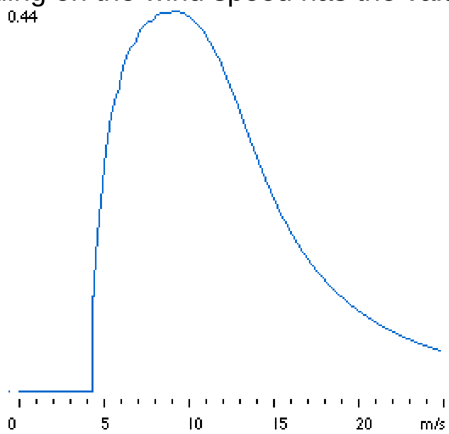


**Fig. 11.** Power coefficient

- *wind energy (*Figure 12)

The amount of energy that the wind transfers to the rotor depends on the air density, the rotor area and the wind speed. Wind energy in an air stream can be viewed depending on:
- the height of the obstacles on the direction of the wind turbine (maximum 30m);
- width of obstacles (maximum 50 m)
- height at the axis of the platform (maximum 50 m);
- roughness / porosity (NaN) (figure 3.5).

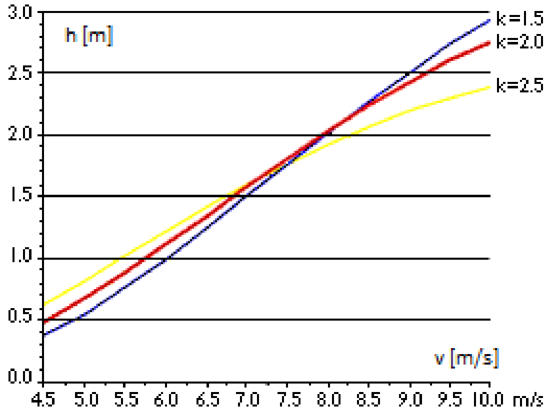


**Fig. 12.** Wind energy

Where
h- height of obstacles [m]; v-wind speed [m / s]; k-shape parameter; k-shape parameter [8]; k = 1.05 ... 0.73; average = 0.94. For average = 5.58 ... 9.98 [m / s] we take k = 0.915 ... 0.900
From the results from the literature, for the case study at an average value of wind speeds, $v_{med}$ = 7.37 m / s, the wind class according to IEC is class III (true = 37.5 m / s). Thus, you can choose a turbine with a nominal power that varies between 1285 ... 1500 kW.
The type of turbine chosen may vary as a model (Table 1):

**Table 1:** Technical parameters on types of wind turbines

| Wind turbine type | Wind class | Rotor Diameter [m] | Tower height [m] | $P_{nom}$ [kW} | $V_s$ [m/s] | $v_0$ [m/s] |
|---|---|---|---|---|---|---|
| VESTAS | IA | 100 | 80 | 3600 | 4 | 25 |
| SIEMENS | IA | 90 | 80 | 3000 | 4 | 25 |
| JIANSGHU NAIR | III | 72 | 62 | 1500 | 6.7 | 25 |

Where
$P_{nom}$-nominal power [kW]; $v_s$- start speed [m/s]; $v_0$- Stop speed [m / s].
Using the data obtained for wind speeds recorded over short and equal intervals, two types of curves can be drawn:
- frequency curve (Figure 13), in which time intervals are associated depending on the frequency of occurrence of the speed

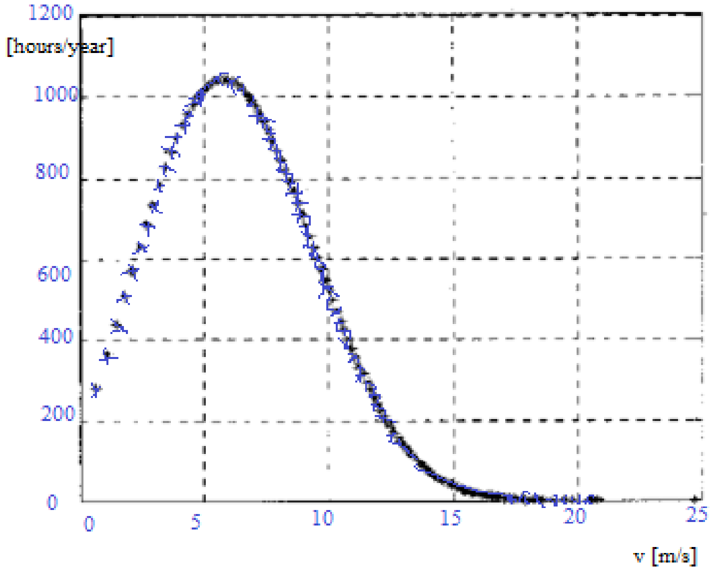


**Fig. 13.** Wind frequency curve

-- the speed assurance curve (Figure 14) in which the dependence between the frequency of occurrence of the speed and the speed threshold is visualized.

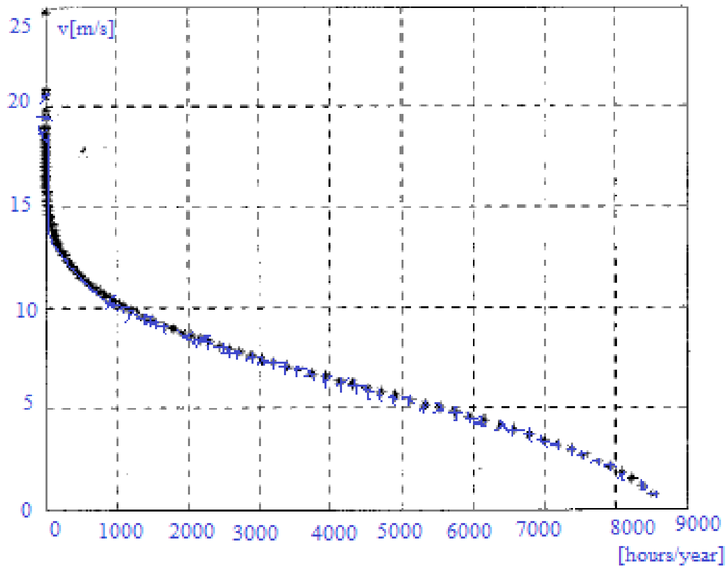


**Fig. 14.** Wind Speed insurance curve

If the speeds and the safety curve are taken into account, it is observed that the wind turbine cannot work at speeds lower than the minimum speed or at speeds higher than the maximum speed. Then it is established what is the optimal speed at which the turbine starts to produce electricity, $v_{min}$, the speed at which it has a maximum energy, $v_{max}$ and what is the installation speed vi, that is, we will make an assessment of the speeds characteristic of the wind turbine location by a simulation in Math Lab.

The results before the revaluation obtained are:

- average speed $v_m$ = 7.389786 m / s; where

$$v_m = \sum_{i=1}^{2000} \frac{v_i}{2000} \tag{2}$$

-maximum speed $v_{max}$ = 24.753 m / s.

Now, after the re-evaluation of the speeds depending on the characteristics of the terrain, the final results are obtained:

- $v_{min}$ = 6.37 m / s;

- $v_{max}$ = 23.5 m / s.

## 3. Conclusions

Wind patterns, turbulence, wind rose, velocity distributions and their frequency were simulated in the context of a chosen location, and the random speed distributions that can be analyzed were finally obtained by using Math Lab Simulink modeling tools, then provided to obtain a maximum power, and consequently a maximum amount of energy.
Thus, it was realized:

- Establishing the wind turbine framing class
- Wind speed variation and turbulence
- Power characteristic and energy produced by turbines.

### References

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