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Assessment of the Wind Field in the East Coast Algerian Regions for the Installation of Wind Farms

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Abstract: Wind is only an intermittent source of energy; it represents a reliable energy resource from a long-term energy policy viewpoint. Among various renewable energy resources, wind power energy is one of the most popular and promising energy resources in the whole world today.
The available electricity generated by a wind power generation system depends on mean wind speed, standard deviation of wind speed, and the location of installation. Since year-to-year variation on annual mean wind speed is hard to predict, wind speed variations during a year can be well characterized in terms of a probability distribution function, as well Weibull distribution has been one of the most commonly used accepted, recommended distribution to determine wind energy potential.
In this study, the two Weibull parameters of the wind speed distribution function (the shape parameter k (dimensionless) and the scale parameter c (m/s)), were computed from the wind speed data for Algerian east coastal regions, records over a 10-year period, 1995-2005.
It was found that the numerical values of both Weibull parameters (k and c) vary over a wide range. The yearly values of k range from 1.20 to 1.94, while those of c are in the range of 4.31 to 1.94.
To minimize the uncertainties of statistical calculation, a spatial representation indicating distribution and occurrence frequency the direction from which the wind comes, appears a very primordial step.
Over the whole valid data during the study period, the compass shows that there is no dominant direction marked. However, we can identify a preferred wind direction.
The statistical results corresponds conformity with the analysis of the rose compass.

Key Words: Wind energy, Weibull parameters, Compass Rose.

1. Introduction

The Renewable energy is abundant and its technologies are well-established to provide complete security of energy supply. It is now evident that renewable energy technologies play a strategic role in achieving the goals of sustainable economical development and environmental protection. With winds fairly constant all year and with availability of large amount of credit and other financial incentives, there is a growing trend for new wind energy installations in the coastal areas of the Algeria, it's has considerably high level of renewable energy resources that can be a part of the total energy network in the country[1]. In practice, it is very important to describe the variation of wind speeds for optimizing the design of the systems resulting in less energy generating costs.

For attracting more and more investors to install new wind farms, creating conditions for a large scale source of renewable electric power generation in the regions. To get a clear assessment of the wind power potential in Algeria, it is necessary to make long meteorological observations in the area.

However, wind as a source of energy is not sufficient to provide continuous electricity because even in the best location wind is variable. If there is no wind blowing no energy can be generated. So, the amount of power that can be harvested from the wind will depend on wind frequency and wind direction (since wind turbines are most efficient when facing into the wind).

Among such observations, the wind speed is an important random variable which affects the most accurate results on the energy potential of the site. The wind speed in a given period may be represented by a probability density function. In recent years the Weibull distribution has been one of the most widely used and recommended tool to determine the potential of wind energy. Moreover, it is used as a benchmark to estimate the wind energy commercially viable.

In this study, the methodology that we implement for the calculation of wind power parameters was based on the study of meteorology over 10 years with a daily rate.

At first glance Weather given by power and direction of wind “Alger Airport” has a good coverage of observations over the Territory, the regions concerned in this study named: **Annaba, Skikda, Jijel, Chlef and Oran** are situated in east coast of Algeria. In order to find a suitable location it is necessary to know spatial distribution of wind, for this reason and for improved allocation data, frequencies of wind direction are presented in this work by a rose compass.

2. Wind Speed Modeling

The main objective of the analysis of wind data is a clearer knowledge of the temporal and spatial variation. Temporal variation includes: - Low frequency (annual variations, seasonal, monthly)
- Medium frequency (changes daily, hourly)
- High frequency (changes to the second or higher frequency)

2.1. Temporal variability and Numerical methods for estimating Weibull parameters

2.1.1. The Weibull distribution “Graphical method”

The wind speed is a random variable and to determine the wind potential of a region it is necessary to use statistical analysis [2, 3, 4, 5].

This requires the existence of time series records of wind speed. Such records are the wind data. Based on the wind speed data collected, the Weibull distribution can be described as a probability density function and a cumulative distribution function, determined by the following equations [6, 7, 8, 9]:

$$f(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} exp\left[-\left(\frac{V}{c}\right)^{k}\right] \quad (1)$$

$$F(V) = \int_0^{+\infty} f(V)\,dV = 1 - exp\left[-\left(\frac{V}{c}\right)^{k}\right] \quad (2)$$

The *k* values range from 1.5 to 3.0 for most wind conditions. The Rayleigh distribution is a special case of the Weibull distribution in which the shape parameter is 2.0. In this distribution method, the wind speed data are interpolated by a straight line, using the concept of least squares. The equation for this method can be represented by a double logarithmic transformation as follows:

$$ln\{-ln[1 - F(V)]\} = k\, ln(V) - k\, ln(c) \quad (3)$$

So, a plot of versus *presents* a straight line. The gradient of the line is *k* and the intercept with the *y*-axis is -*k* ln *c*. The two significant parameters *k* and *c* are closely related to the mean value of the wind speed

$$\bar{V} = c\,\Gamma\left(1 + {}^{1}/_{k}\right) \quad (4)$$

2.1.2. Maximum likelihood method

The maximum likelihood estimation method is difficult to solve, since numerical iterations are needed to determine the parameters of the Weibull distribution [10]. In this method, the parameters k and c are determined according to the equations below [11]

$$k = n\left[\frac{\sum_{i=1}^{n} V_i^k\, ln(V_i)}{\sum_{i=1}^{n} V_i^k}\right] \quad (5)$$

$$c = \left[\frac{1}{n}\sum_{i=1}^{n} V_i^k\right]^{1/k} \quad (6)$$

Where n is the number of observations performed and V_i is the wind speed measured at the interval i.

2.1.3. Moment method

The moment method can be used as an alternative to the maximum likelihood method [12] and, in this case, the parameters k and c are determined by the following equations:

$$c = \frac{\bar{V}}{\Gamma\left(1 + {}^{1}/_{k}\right)} \quad (7)$$

$$\delta = c\left[\Gamma\left(1+{}^{2}/_{k}\right) - \Gamma^{2}\left(1+{}^{1}/_{k}\right)\right]^{\frac{1}{2}} \quad (8)$$

2.1.4. Empirical method

The empirical method is considered a special case of the moment method, where the Weibull parameters k and c are given by the equations shown below [13, 14].

$$k = \left(\frac{\sigma}{\bar{V}}\right)^{-1{,}086} \quad (9)$$

2.2. Special Variability

2.2.1. *Vertical Wind Speed Variation*

Very often, measures wind speeds are taken at a different height at which wind turbines are installed. It is therefore necessary to determine a relationship between wind speeds varying heights, the formula expressing the speed gradient is logarithmic but normally approached by a potential form:

$$V_2 = V_1\left({}^{z_2}/_{z_1}\right)^{\alpha} \quad (10)$$

The wind profile indicates the average wind speed based on the height z_2 above the ground. V_1 is the reference speed at the height z_1, and α is the empirical parameter of the law potential [15]

2.2.2. Wind Direction

Wind roses are circular, graphical displays of wind speed, direction, and frequency based on a simple compass rose. Wind direction is shown by the length of a line representing a number of wind collection events. The length of the line from the outer circle to the center of the rose shows the percentage of total wind measurements where the wind blows from that compass direction – incorporating both frequency and direction data. Wind speeds are shown using a number of different techniques. Indeed, during the wind turbines installation on a site, it is necessary to know where the principal directions of the wind in order to limit the negative interaction between several wind and obstacles. Therefore, the wind roses give more information.

3. TOPOGRAPHY

The topographic study over the years "1995-2005" has given practical information on meteorological conditions and specific wind condition of various cities of Algeria; we are interested only in this work on Algerian east coast regions such as "Annaba, Skikda, Jijel, Alger, Chlef, and Oran"

4. R ESULTS AND DISCUSSION

4.1. Parameters weibull resultants

Figures 1, 2, 3, 4, 5, and 6 show the Weilbull distribution, described by its probability function, versus the mean wind speed, for data collected on an annual basis from 1995 to 2005, for the cities of East Cost of Algeria, based on parameters calculated using the weibull methods presented in previous section. The annual parameters weibull k and c as well as the standard deviation data observed in the all cities over 10 years are shown in Table 1.

Table 1. Coefficients values of k and c

station	*Annaba*		*Skikda*		*Jijel*		**Alger**		**Chlef**		**Oran**	
Years	**k**	**c**	**k**	**c**	**k**	**c**	**k**	**c**	**k**	**c**	**k**	**c**
1995	1,63	3,91	1,89	4,09	1,48	2,08	1,41	2,29	1,59	2,93	1,82	3,83
1996	1,82	3,78	1,96	3,57	1,44	2,41	1,29	2,42	1,76	2,86	1,92	4,25
1997	1,82	3,79	1,89	3,29	1,33	2,60	1,53	2,15	1,51	2,61	1,84	3,21
1998	1,84	3,87	1,64	3,10	1,32	2,56	1,30	1,94	1,53	2,72	1,69	3,38
1999	1,94	4,31	1,84	3,13	1,61	2,97	1,66	2,54	1,43	3,00	1,52	3,39
2000	1,81	3,73	1,36	2,74	1,41	2,25	1,38	2,82	1,59	2,89	1,61	3,04
2001	1,59	3,72	1,57	2,83	1,45	2,40	1,56	2,82	1,61	2,97	1,64	2,08
2002	1,63	3,87	1,36	2,71	1,48	2,53	1,35	2,66	1,74	2,79	1,44	2,08
2003	1,66	4,04	1,60	2,94	1,32	2,57	1,55	2,75	1,49	2,53	1,61	2,08
2004	1,84	3,86	1,70	3,33	1,22	1,69	1,61	2,41	1,73	2,76	1,66	2,08
2005	1,85	3,82	1,42	2,99	1,20	2,11	1,50	2,59	1,51	2,59	1,50	2,08
11 ans	1,63	3,89	1,57	3,16	1,27	2,38	1,30	2,49	1,38	2,79	1,50	3,34

Furthermore, from Figs. 1 to 6 it is possible to verify how the curves representing the yearly Weibull probability density function, for each of the six cities "Annaba, Skikda, Jijel, Alger, Chlef, and Oran" along 10 years :1995 to 2005. The probability density distribution shape develops the real data set around the average speed for small values of k distribution is wide, however, the data distribution is very narrow for large values of k and beyond k = 3 the distribution obeys a normal law. Generally the average wind speed is between 1.5 to 4 m/s for all the regions studied

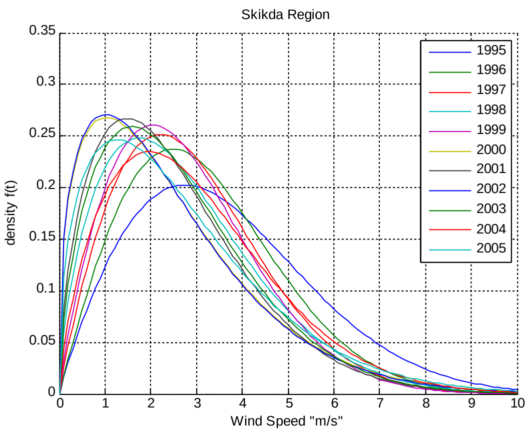


Figure 1 .*The Weibull probability density of Annaba*

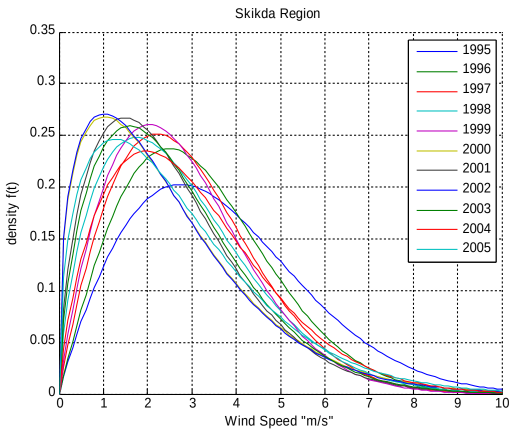


Figure 2. *The Weibull probability density of Skikda*

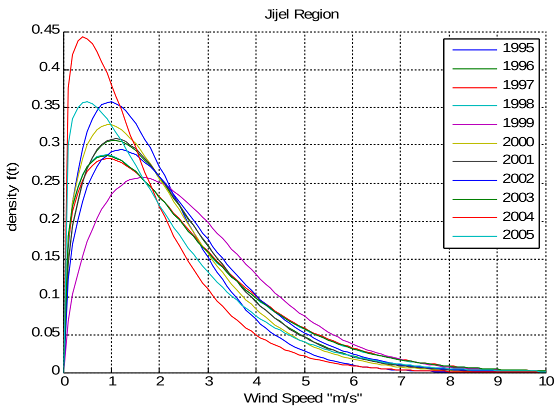


Figure 3. The Weibull probability density of Jijel

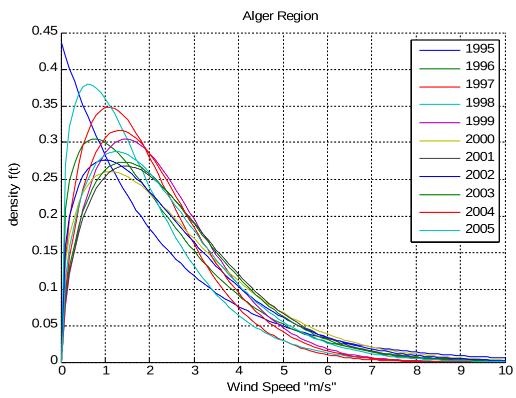
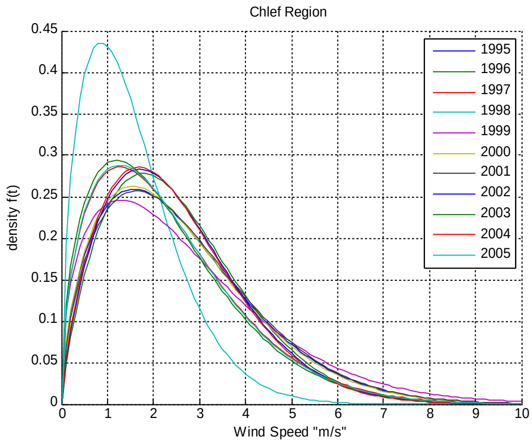


Figure 4. The Weibull probability density of Alger



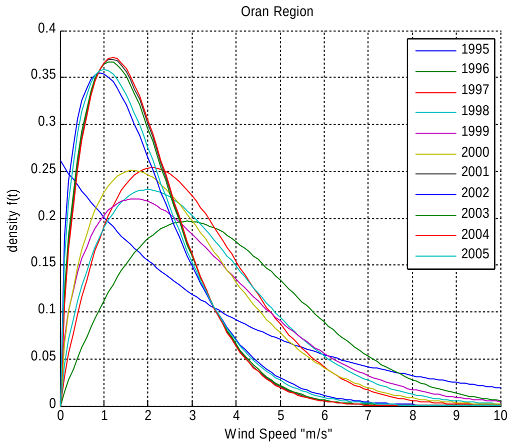


Figure 5. The Weibull probability density of Chlef

Figure 6. The Weibull probability density of Oran

4.2. Compasses rose results

To improved knowledge idea of the wind speed distribution and directions, rose compasses were studied from meteorological data to the six regions mentioned previously.

compass rose of Annaba region (figure 7) shows that wind directions are distributed on an almost similar in all regions and with equal percentages (figure 8), however the wind almost neglected in the direction north-west and south-east, with a calm wind 20 3% in the South-South.

The winds are the most frequent wind speed between 1 and 6 m/s (55, 3% Occurrences), these winds are 30% of the south side.

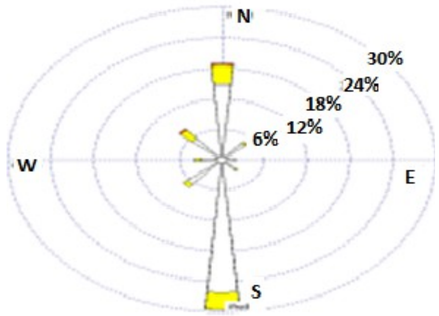


Figure 7. Compass rose "Annaba"

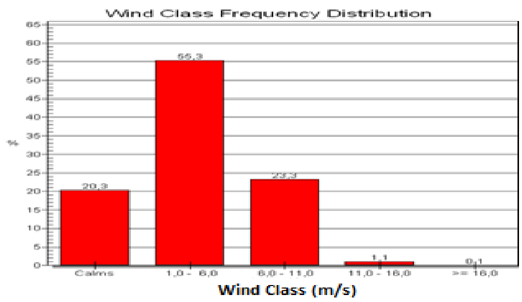


Figure 8. Wind class frequency distribution "Annaba

The Annual compass rose of the Skikda region (figure 9) in the period (1990-2007) shows the prevailing wind direction is south-south, and the second dominant direction is North-South, while other directions are neglected. All directions have a low speed varied between 1-6 m/s, with higher values of wind have a very low rate of occurrence (figure 10).

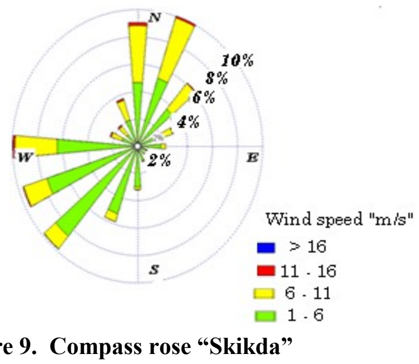


Figure 9. Compass rose "Skikda"

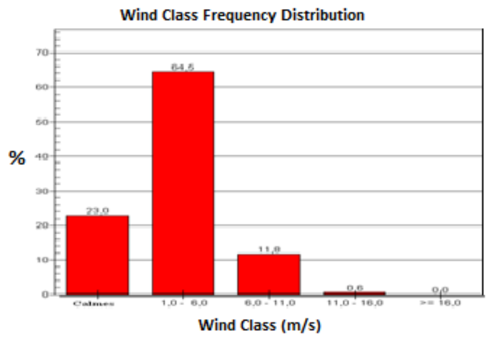


Figure 10. Wind class frequency distribution "Skikda"

Figures 11 and 12 show the compass rose speed and the percentage classes in the Jijel region. It was found that:

- The winds are the most frequent wind speed equal to 1 and 6 m / s (40, 3% of occurrences) and between 6 and 11 m/s (17.5% of the occurrences),These winds are from the Nord-West.
- The calm winds have a percentage of 40.9% in all directions,
- Strong winds (speed exceeding 16m/s) were not observed during this period.

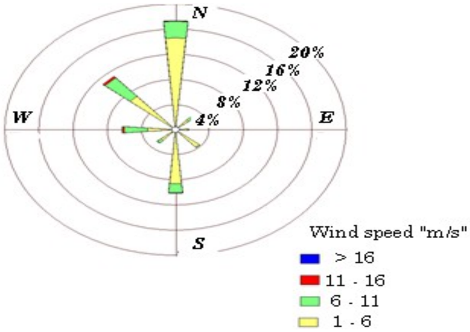


Figure 11. Compass rose "Jijel"

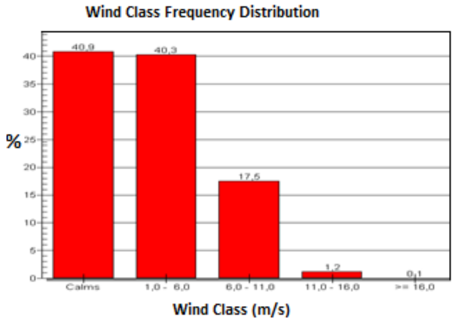


Figure 12. Wind class frequency distribution "Jijel"

Figures 13 and 14 show the compass rose speed and the percentage classes in Alger region. It was found that:

- The winds are the most frequent wind speed equal to 1 and 6 m / s (40, 3% of occurrences) and between 6 and 11 m / s (17.5% of the occurrences). These winds are from the south-West mostly
- The calm winds have a percentage of 40.9% in all directions,
- Strong winds (speed exceeding 16 m / s) were not observed during this period.

The both histograms of wind class frequency distribution (of Jijel and Alger) have the same distribution.

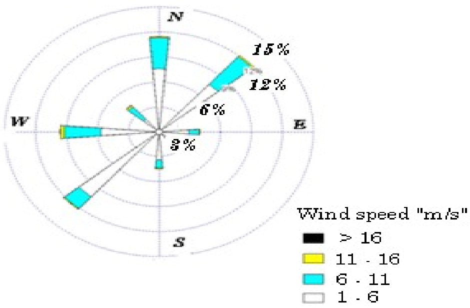


Figure 13. Compass rose "Algiers"

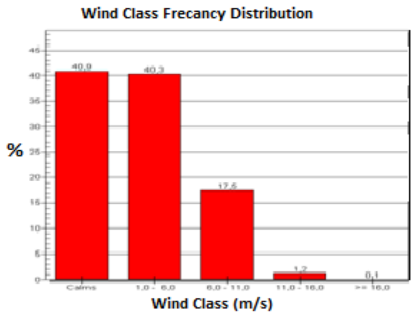


Figure 14. Wind class frequency distribution "Alger"

Figures 15 and 16 show the compass rose speed and the percentage classes in Chlef region, we find that:

- The winds are still the most frequent wind speed equal to 1-6 m/s (53.8% of Occurrences) and between 6 and 11 m/s (13.8% of occurrences) and are almost in all directions.
- The weak winds (speed less than 1 m/s) have no preferred direction,
- High winds (speed exceeding 16 m/s) represent 0.6% of the data and come, mostly from West and South-West.

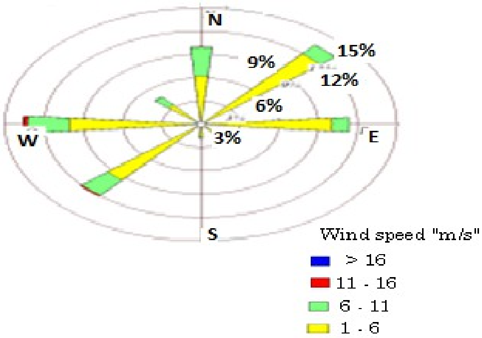


Figure 15. Compass rose "Chlef"

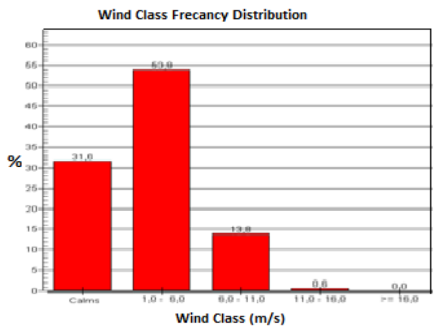


Figure 16. Wind class frequency distribution "Chlef"

Figures 17 and 18 show the compass wind speed and the percentage classes in Oran region, we find that:

- The winds are always the most frequent wind speed equal to 1 m /s to 6 m / s (55.7% of occurrences) and between 6 and 11 m/s (25.1%). These winds are mostly from all directions and northern West for wind between 6 and 11 m / s,
- The feeble winds (speed less than 1 m / s) have no preferred direction,
- A high wind (speed exceeding 16 m / s) represents 3% of the data and come mostly in the South.

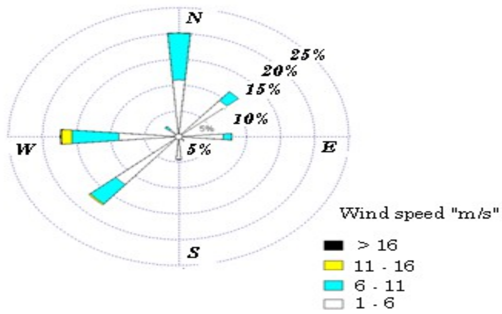


Figure 17.Wind compass "Oran"

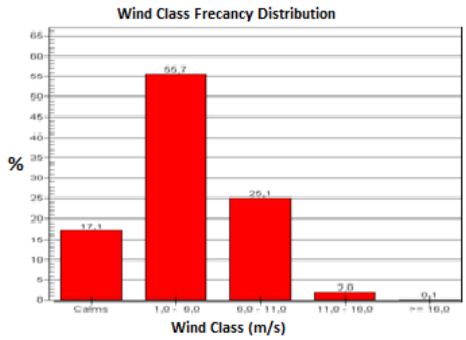


Figure 18. Wind class frequency distribution "Oran"

5. CONCLUSION

This work focuses on the estimation of wind power in east coastal region of Algerian must drive the development of wind power in Algeria. The research consists of the study of a phase prior to provide effective assistance to all those who have to make decisions about the planning and implementation of projects Wind Power. In this perspective, we began by determining various parameters related to the wind, such as the mathematical modeling of the frequency distribution of wind Weibull distribution and treatment simulation and real data collected on the wind over 10 years to size a wind farm on a cities. It has been estimated wind power potential, while relying on the automatic determination of the direction of the wind sites in study subjects. Parameter values measured using the rose compass is very close approximation of the values obtained by mathematical modeling of Weibull distribution, which validates our study. Consequently a result of all valid data during the study period, the compass shows that there is no dominant direction marked. However, we could identify preferred directions of the wind.

Nomenclature

Symbols	Name, *unit*	Symbols graces	
C	dimensionless Weibull shape parameter	Γ	Gamma function
K	dimensionless Weibull scale parameter	δ	Standard deviation of the observed data
V	wind speed (m/s)		
Z	height (m)		

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