IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 08, Issue 11 (November. 2018), ||V (II) || PP 44-50

Wind power estimation of three locations of Tangier-Tetouan region

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Abstract—It is very important to analyze the wind characteristics of a region in order to acquire the maximum wind potential from the site, since wind speed fluctuates rapidly over time, some critical errors might occur between the estimated and the actual energy output. The main objective of this study is to improve the predictability of wind generation, these include to propose a probabilistic prediction approach of the moment of appearance of these variations. In this perspective, we will carry out a comparison between three sites in Morocco to arrive at an accurate location, in order to size a wind farm.

Keywords- Wind speed; Wind power density; wind variation; Statistical analysis; Weibull; probability density function.

Date of Submission: 11-11-2018 Date of acceptance: 23-11-2018

I. INTRODUCTION

In the last decades High growth of world population and socio-economic development has caused the increase in energy demands , energy demand will continue to increase significantly in the coming years, according to some predictions it will reach 700-830 EJ by 2040 [1].Consequently in order to reduce Greenhouse gases many developed and developing countries have adopted policies for the use of renewable energy sources such as solar, hydroelectric, geothermal and wind energy The wind is a clean, free, and readily available renewable energy source. Each day, around the world, wind turbines are capturing the wind's power and converting it to electricity, this source of power generation plays an increasingly important role in the way we power our world., electricity generation by wind power has captured considerable attention worldwide and has been a topic of great interest for developers and researchers, but wind speed variability effect the estimation of wind power consequently the financial side, in this perspective it is essential to study the statistical characteristics of wind speeds in a specific site because they are related to the assessment of wind energy potential, design of wind farms and power generators, and operation management of wind power conversion systems. The statistical characteristics of wind and the selection of suitable wind turbines are important optimize the profits from the wind energy production and design wind farms, since wind speed fluctuates rapidly over time, some critical errors might occur between the estimated and he actual energy output and using statistical methods leads to a sophisticated estimation of the energy. Many researchers have been using several methods to predict the wind potential of a specific wind field, In most studies, Weibull distribution was the most commonly used to deduce the assessment of wind power density, Mirhosseini et al. [2] studied the 3-h wind speed data for 4 years (2003–2007) to evaluate the potential of wind power in the Semnan province of Iran. Results of Weibull distribution showed that the Damghan city had better wind potential for installation of wind farms, Ali, Lee and Man Jang [3] analyzed wind characteristics using two variables Weibull and Rayleigh PDF in Deokjeok-do which is a small island situated in the west of South Korea. Wais [4] compared the two and three-parameter Weibull distributions directly for wind energy calculations, and he checked whether or not the three-parameter Weibull distribution can take advantages comparing to the typical Weibull distribution for high percentages of null wind speeds. Pishgar and Akram [5] examine the wind energy potential by finding the Weibull and Rayleigh distribution parameters, [6] MertKantar and Usta used upper-truncated Weibull distribution, in modeling wind speed data and also in estimating wind power density. GülAkgül, Şenoğlu and Arslan [7] used the Inverse Weibull (IW) distribution to model the wind speed, In order to determine the available power and energy density, but the two-parameter Weibull distribution is not always effective to evaluate the wind speed distribution, Brano et al. [8] analyzed the wind speed characteristics of the urban area of Palermo by comparing seven PDF (Weibull, Rayleigh, Lognormal, Gamma, Inverse Gaussian, Pearson type V and Burr), the Burr probability density function was the most accurate statistical function for the wind speed distribution. The purpose of this study is to reveal for the first time the wind power potentials of three sites in Tangier-Tetouan region (ASSILAH, HRARZA, and TETOUAN) and to provide a comprehensive wind map of the region. Fig.1. shows the map of all sites.

Fig. 1. Map of the locations

II. DATA ANALYSIS

The data of (ASSILAH, HRARZA, TETOUAN) was collected from METEONORM software, the height of the anemometer is 50m ground level , and the wind data, including wind speed and wind direction, were recorded for three years (Jan. 2013 to Dec. 2015) with 1hour time interval. According to international standards, wind data should be collected for more than one year to increase confidence in the results. Table 1 shows the brief details about recorded data. For the density's distribution, we will use the hourly wind speed. The parameters will be estimated by maximum likelihood method (MLE) and the simulation is done by **R** software.The wind rose diagrams are presented in (Fig.2, 3, 4). The wind rose diagram summarizes the wind characteristics for a specific time period to find out the dominating wind directions so that we can determine the optimal position of wind turbines. As the figures shows although the wind power at each site varies significantly, however, the prevailing wind direction for all sites is dominated by eastern wind.

The observed wind directions and wind speed are due to the climate characteristics of the region as seasonal monsoons (especially in the summer). Monsoons are the result of temperature differences between land and sea, this temperature difference influence the wind characteristics such as mean wind speed and fluctuations in wind speed.

Table 1: Detail collected data position

Location	Longitude	Latitude	Time interval	height (m)
ASSILAH	**-6 °**	**35.5°**	**1 Hour**	**50m**
HRARZA	**-5.625°**	**35.50 °**	**1 Hour**	**50m**
TETOUAN	**-5.33°**	**35.5°**	**1 Hour**	**50m**

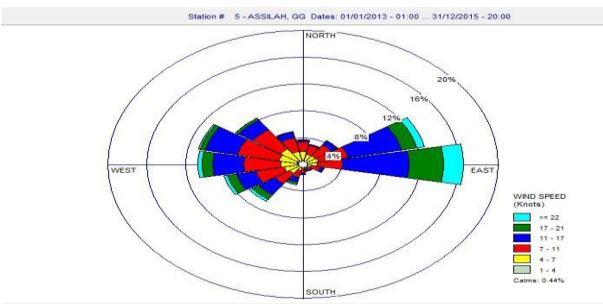


Fig. 2. Windrose diagram of ASSILAH by WRPLOT (2013-2015).

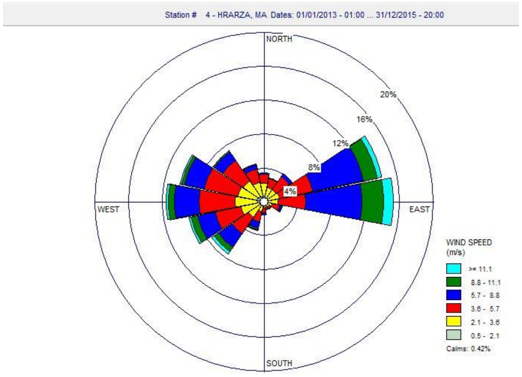


Fig. 3. Windrose diagram of HRARZA by WRPLOT (2013-2015).

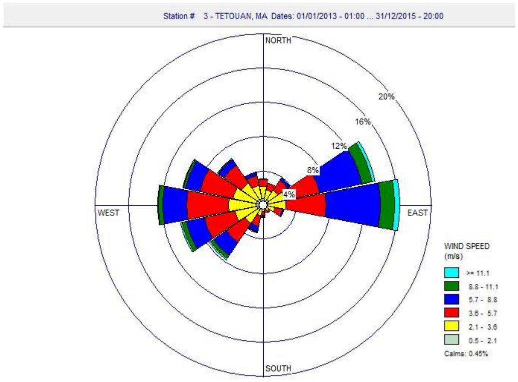


Fig. 4. Windrose diagram of TETOUAN by WRPLOT (2013-2015).

A correct statistical analysis of wind data is an important phase in a wind resource evaluation, Table 2 presents the statistical details of the data of each city. The choice of the site influences the estimation of the available wind energy or the wind turbine performance and gives the significant impact on the investment profitability. The Weibull distribution model allows a good approximation of the distribution of the wind speed, because of its ability to assume the character the Wind speed. Many studies have shown that the two-parameter Weibull distribution provides a good prediction of the wind energy potential. In this study, we will compare the Weibull probability distributions obtained from three different locations. The parameters will be estimated by maximum likelihood method (MLE).

III. WEIBULL ALTERNATIVE PROBABILITY MODEL

Proposed by the Swedish engineer and mathematician Ernst (Hjalmar Waloddi Weibull (1887-1979)), is a law of continuous probability. Weibull's law is a special case of generalized extremum law in the same way as Gumbel's law or Fréchet's law. It PDF is as shown in equation (1).

$$f(v) = (\frac{k}{c})(\frac{v}{c})^{(k-1)}e^{(\frac{-v}{c})^k} \quad (1)$$

v : wind speed $\left(\frac{m}{s}\right)$

$(k, c > 0$: Weibull parameters$)$

The cumulative distribution function for the Weibull distribution is:

For $v > 0$:

$$F(v) = 1 - e^{(\frac{-v}{c})^k} \quad (2)$$

for $v \leq 0$:

$$F(v) = 0$$

IV. STATISTICAL ANALYSIS OF EACH SITE

The parameters were estimated using maximum likelihood minimization method to estimate the parameters (Cohen (1965)) [9]. This method is easy simple tools and consists to maximize the product density:

$$f(x) = \prod_{i=1}^{n} f(x_i, \theta) \qquad (3)$$

Where θ consists the set parameters to be estimated.

Fig. (5, 6, 7) shows histogram of the wind speed data and the fitted probability density function. We observe that PDF of all sites adjust well the empirical value in the centre. Moreover, the peak of the PDF represents the most frequent wind speed occurred for all sites, for example for ASSILAH It can be observed from Fig. 4 that the most frequent wind speed is about 4,8 m/s which is consistent with the Median of estimated Weibull distribution using the annual data of ASSILAH in Table 2. As we notice in Table 3 the value of k remains close to 2, which means that the wind distribution is regular and uniform. For $k < 2.6$, the Weibull PDF has a right tail. For

$2.6 < k < 3.7$, the Weibull PDF may approximate the normal PDF.

Table 2: Statistical details

Site	Min (m/s)	Mean (m/s)	Median (m/s)	Max (m/s)
ASSILAH	0.09	5.49	5.08	16.7
HRARZA	0.02	4.668	4.250	18.33
TETOUAN	0.03	3.857	3.68	10.40

Table 3: Statistical estimation of the parameters

Site	Parameters
ASSILAH	K=2.102 C=6.200
HRARZA	K=2.112 C=5.278
TETOUAN	K=2.442 C=4.350

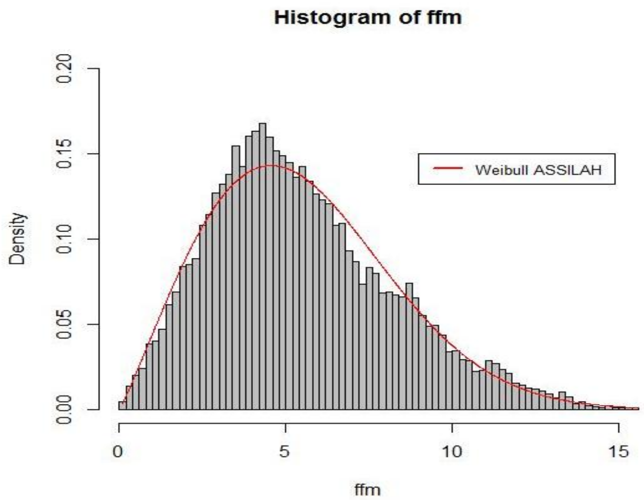


Fig. 5. The distribution 's density of ASSILAH

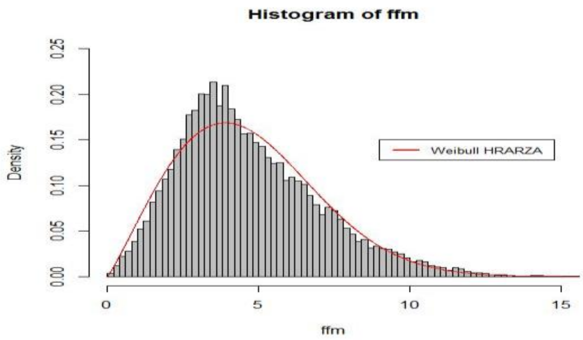


Fig. 6. The distribution 's density of HRARZA

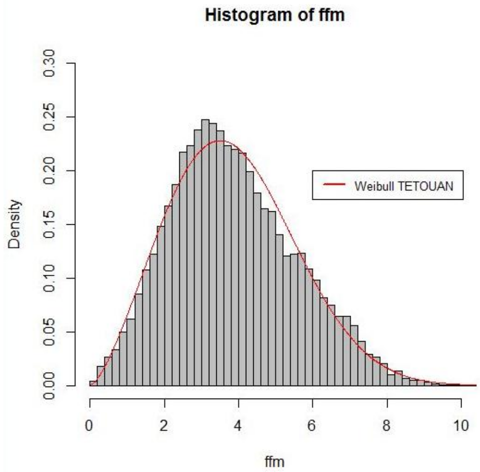


Fig. 7. The distribution 's density of TETOUAN

V. WIND POWER ENERGY

Estimation of the available energy in the wind at a site, in which the wind turbine will be, is one of the essentials steps in the planning of a wind energy project. The available power of the wind is:

$$P = \frac{1}{2}\dot{m}v^2 = \frac{1}{2}\rho A v^3 \text{ With } \dot{m} = \rho A v \qquad (4)$$

A: the cross sectional area

Mean wind speed:

$$v_{moy}^3 = \int_0^\infty v^3 f(v)dv \qquad (5)$$

MEAN WIND POWER:

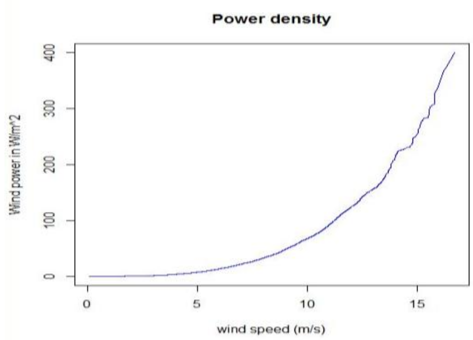
or: $$P = \frac{1}{2}\rho A \int_0^\infty v^3 f(v)dv \quad (6)$$

The available wind energy and power can be given by:

$$E = \frac{1}{2}\rho A T_Y \int_0^\infty V^3 F(V)DV \qquad (7)$$

f(v): the density of the chosen model

Eq. (6) and Eq. (7) enable to calculate the available wind energy and wind power directly from the measurements. The simulation is for the hourly wind speed of each day during three year, the total number of hours, for one year is t_y. The available wind power and energy can be estimated by adding up the energy corresponding to all wind speeds. Fig. (8, 9, 10) present the estimated power of the three locations using Weibull method. While It can be noticed that. The highest value of wind power density was found at ASSILAH (400 W / m2) followed by HRARZA (300 W / m2). Whereas the lowest wind power density was observed at TETOUAN (150 W / m2).



. **Fig. 8**. Estimated power of ASSILAH

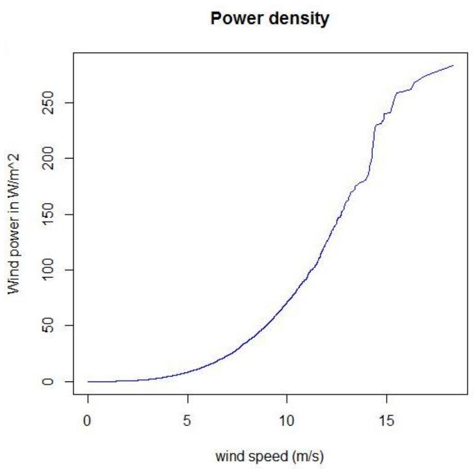


Fig. 9. Estimated power of HRARZA

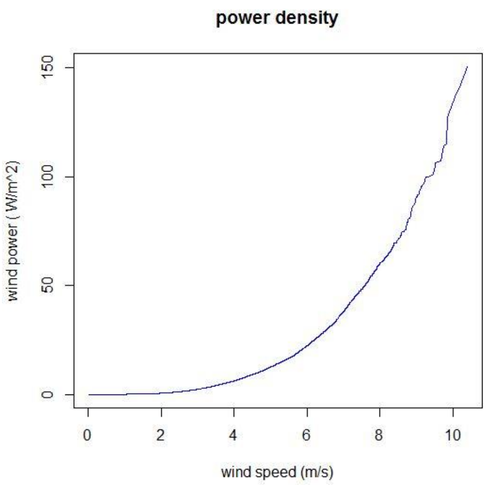


Fig. 10. Estimated power of TETOUAN

VI. CONCLUSION

In the present paper, the wind speed and wind direction data of four sites from 2013 to 2015, have been statistically analyzed. Mean wind speed, and k & c Weibull parameters have been calculated. Wind direction trends were analyzed and summarized in a wind rose diagram, the annual mean power densities have been calculated and were used to evaluate the wind energy potential of those locations. The results below shows us that the most accurate site for wind farms is ASSILAH based on it wind power density.

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Fatima Bahraoui. " Wind power estimation of three locations of Tangier-Tetouan region.” IOSR Journal of Engineering (IOSRJEN), vol. 08, no. 11, 2018, pp. 44-50.