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Statistical Analysis of Wind Speed and Direction in Matehuala, S.L.P.

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***Abstract*—The analysis of wind speed and direction in the region of Matehuala, Mexico is presented, in order to determine if weather conditions are conducive to harnessing wind energy. To analyze were used climate data from 2010 to 2015 in the study region and different patterns of wind speed and direction established by defining the minimum and maximum values, and wind fluctuations in each season.**

The results showed that the highest wind speeds occur during the nights in the spring season and the end of the summer season with a range of average speeds of 2.2 m / s to 6.1 m / s. In addition, average wind speeds prevail throughout the year are with a range of 2.2 m / s to 4.1 m / s. These results suggest that the study area may be suitable for the generation of electrical or mechanical energy to small scale, with several small turbines connected together to generate enough electric power.

Keywords*—*Wind speed and direction, Wind rose, Beaufort scale.

I. INTRODUCTION

In today's world, the clean and safe energy are being needed [3]. Wind is one thermal comfort element of urban spaces and is known since ancient times its healthy-effects, thermal and climate. Wind behaviour is certainly affected by vegetation; this condition affects the characteristics of the mobility in the air currents and helps to generate mechanical turbulence which benefits to reduce thermal turbulences favouring the temperature control [4]. Environmental and political concerns for sustainable development have encouraged the growth of electricity generation from renewable energies. The wind energy is seen as one of the most practical options; furthermore, this energy type presents better cost-benefit. In a remote place where it is not feasible to access a public electrical grid, the consumers of this energy are in obligation to invest in motor-generators units (Diesel), the cost of operation increases in relation with the petroleum prices. At the present time, researchers and companies in the world are doing efforts to consume less petroleum by incorporating hybrid systems in its various presentations (thermal-wind, wind-diesel, etc.). Currently, integrated electrical systems to wind generation cover a small part of the total power demand, where the major of the generation power is given by other sources such as hydro, nuclear and fossil fuels [6].

The wind behaviour studies are important to determine the viability of wind power. This unconventional source of energy has not been exploited by man at a commercial scale [7]. Wind power is shown as a technical and economic alternative with the potential to be implemented in areas with feasible meteorological characteristics in order to meet energy needs [8].

Wind power systems have one of the best cost/benefit ratios for renewable energy applications in homes, as they help reduce electricity bills between 50 and 90%. It is important to mention that commercial wind turbines for homes need a minimum wind speed of 3m/s to start its operation and an average of average speed of 10 m/s to achieve maximum efficiency [20].

In general, the calculation of energy production and energy saving are done primarily through the classical methodology of calculation generated energy, usable, and useful dissipated. This methodology considers the calculation of the occurrence probability of wind speed, Weibull's probabilistic models in its different versions and Rayleigh model (used for the implementation of a wind turbine according to the characteristic curves of the wind speed) [5].

The evaluation of a wind system is extremely important to consider the behaviour of the wind speed, which consists of the three components sum: components ramp, gust and turbulence; these components collect potential dominant phenomena in time series. Therefore, the wind speed is an independent variable, it is also necessary to model because it is essential to describe the performance of the wind turbine [18].

The aim of the analysis is to determine the wind conditions in the region of Matehuala S.L.P. (Place located in the San Luis Potosí, Mexico) in order to the implementation of commercial wind generators for small scale production. The behaviour of wind for an average a year and each of its seasons are analysed. The main study variables are wind speed and direction. The wind direction is defined using a compass rose or windrose which is evaluated annually in each season of year. The evaluation of the wind direction in the region and the behaviour of the average levels of speed are established.

II. BACKGROUND

The current demand for clean energy has generated many places develop feasibility studies focus on the use of wind to generate electricity or simply mechanical energy , and therefore determine whether the range of prevailing wind speeds are able to produce energy using commercial wind turbines. In the Neuquen province a wind analysis using data from the annual average in the period 1968-1996 was realized. The results showed the wind intensity and variation on different regions in Neuquen province [9]. On the other hand, the urban areas in Colombia, the conditions for

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modelling the of wind speed were performed to calculate the wind power density for each location [10]; with these results, the authors determine appropriate areas for electrical applications using wind turbines, and inter-connection to the power grid [10]. The characteristics of the surface are important factors in wind behaviour. In this sense the authors of [12] present the analysis of the mean wind direction and wind maximun every 15 minutes under complex terrain conditions. These authors conclude that the behaviour of temporary variables can be considered as a mixture of several spatiotemporal independent signals, these signals occur with varying intensity; five weather stations were analized in the Llobregat river basin in order to determine the wind behaviour and establish the direction and speed wind, which depend the local orography and land topography. Furthermore, they found that the higher wind speeds are reached in hours with more weather hazard, i.e., weather with high temperature and low humidity [12]. Others works of wind analysis utilize statistical tools for managing climate data. In [11] a wind analysis to each statistical indicator was presented, these one take average values of each month, direction and the annual average wind speed. In [15] a variability analysis for wind mean speed was presented. In this one, an analysis of variability of mean wind speeds through the static and probabilistic analysis was performed. The authors indicated that the wind is a variable directly related with time duration of the data collected. The use of probability techniques can help predict the wind behaviour. In [13] the analysis of wind speed measurements using the technique of outliers values was presented. This work presented the probability curves from wind speed histogram before and after of the technique. They found that the best fit to data to the histogram curve is by using probability models with reduced statistical errors in the quantitative analysis. Further, the Weibull method was used to obtain the averages of the variables for 5 years (2007-2012). With this, the authors obtain the wind characteristics by using variables such as wind speed, wind direction and air temperature. In addition, they propose a least-squares fit of the maximum values, such values are used to propose a suitable commercial wind turbine in order to obtain energy in the study region and the orientation of the wind turbine [12]. It is noteworthy that the Weibull function is a useful tool for the characterization of direction behaviour, speed and burst duration of the wind [17]. Spectral analysis was used to determine the variability and prevailing wind direction in [14], this analysis presents the dynamic complexity which depends on the seasons from summer to winter due to variations caused by weather events. The authors of [19] established the following with respect to Lake Maracaibo Basin,Venezuela: the significant increase in wind speed with height is a very important aspect. They established that the height will be an important factor from wind speeds and relative change for each season. In an analysis of building construction in the city of Barcelona establish the use of the Table of wind dynamic pressure according to the Basic Building Regulations NBE-AE-88. This table establish the wind pressure according to its speed and altitude of data collection. This pressure determines that at higher altitudes more wind speed; hence dynamic pressure is higher [16]. Currently, there are no wind characterization studies in the region of Matehuala, S.L.P. Hence, this zone is conducive to the implementation of projects focused on wind energy because is a type of energy renewable, clean, free and natural. In this work, the analysis speed and wind direction is presented. The aim of the analysis is to determine the weather conditions in the region of Matehuala S.L.P. (Place located in the San Luis Potosí, Mexico) in order to the implementation of a wind generator. The main study variables are speed and wind direction. The wind direction is defined using a compass rose, which is evaluated annually in each season of year. The evaluation of the wind direction in the region and the behaviour of the average levels of speed are established.

III.METHODOLOGY

A. Weather variables

Wind speed and direction of the region were the variables of interest. These data were obtained from the climatological database of the National Water Commission (CONAGUA). The data were taken with a sampling of 10 minutes over a period of 6 years (2010-2015) giving a total of 144 measurements per day.

It is essential to know the values of speed and the intensity of trajectories of air masses in order to study phenomena related to wind [1]. The prevailing wind in a time range can be represented by a compass rose, which indicates the percentage of time that the wind blows from different directions. The graph consists of using rods or extensions ranging from the centre of a circle to a particular point illustrating the wind direction. The length of each extension indicates the percentage of time that the wind headed that direction. In this work the analysis of wind speed and direction was analysed by a computer package for statistical analysis.

B. Wind speed

The intensity of wind speed is defined and classified by the Beaufort scale or Beaufort wind force scale. This is an empirical measure that relates wind speed to observed conditions on land and it is used as an international benchmark to characterize the winds [2].

Table 1. The Beaufort scale

Force	Velocity (m/s)	Velocity (km/h)	Description
0	0 - 0,5	0 - 1	Calm
1	0,6 - 1,7	2-6	Ligth air
2	1,8 - 3,3	7-12	Gentle Breeze
3	3,4 - 5,2	13 -18	Moderate Breeze
4	5,3 - 7,4	19- 26	Strong Breeze
5	7,5 - 9,8	27 - 35	Near Gale
6	9,9 - 10,4	36 - 44	Gale
7	12,5 - 15,2	45 -54	Storm
8	15,3 - 18,2	55 -65	Violent Storm
9	Over 19	Over 66	Hurricane

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C. Wind direction

To determine the wind direction was taken as proposed in [1]. The table 2 is used for the successful completion of the compass rose. In the other hand, the Table 3 is used for the analysis of the year seasons [1].

Table 2. Symbology used for wind directions

Direction	Simbol	Orientation
North	N	360°
North North East	NNe	22.5°
North East	NE	45°
East North East	ENE	67.5°
East	E	90
East South East	ESE	112.5°
South East	SE	135°
South South East	SSE	157.5°
Sourth	S	180°
South South West	SSW	202.5°
South West	SW	225°
West South West	WSW	247.5°
West	W	270°
West North West	WNW	292.5°
North West	NW	315°
North North West	NNW	337.5°

Table 3: Seasons of the year

Season	Period	
Spring	21 March	20 June
Summer	21 June	20 September
Fall	21 September	20 December
Winter	21 December	20 March

Once the main analysis variables defined: speed and wind direction, the statistical analysis of climate data is developed to obtain as results the trend, the classification and the dominant periods of the wind in the study area. For this, the methodology used is presented in Figure 1

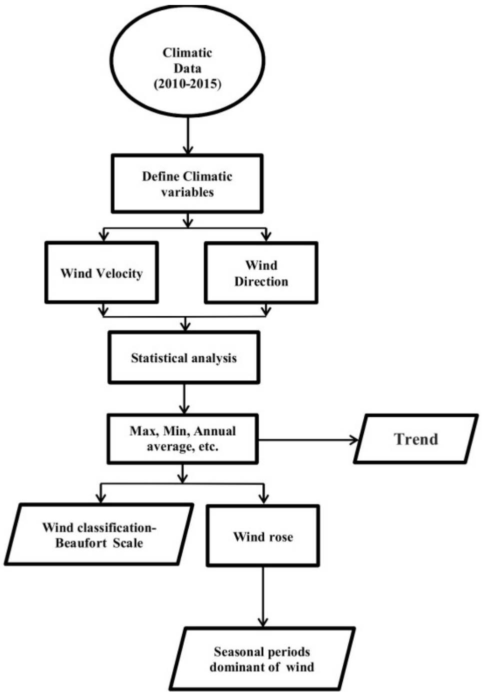

Fig. 1. Flow Diagram of Methodology

IV. RESULTS

Figure 2 shows the variation of wind speed in the region throughout an average day for each month during the years 2010 to 2015. The results show that maximum wind speeds is of 6 m/s, according to Beaufort scale this speed defines a wind type 'Strong Breeze' .It is also observed that a minimum wind speed of 0 m / s classified as a wind type 'Calm'

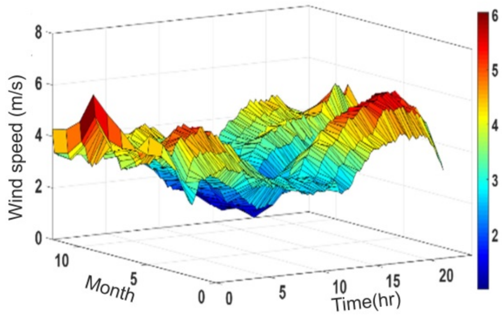

Fig. 2. Wind speed ratio (m/s) - Months - Time (hours)

Figure 3 shows the variation of wind speed during a typical day where the transition is shown for each month. This figure shows that the early hours of the morning the winds are in range of 2.9 m / s to 6 m / s. This is a wind type 'Gentle and Moderate Breeze 'and fluctuates during the first hours. The wind speed tends to decrease, its speed arriving soft winds, light winds and calm winds in an average of approximately 3 hours, after that time, the wind increases and its speed on the last remaining hours reaching a maximum of 6m / s speeds.

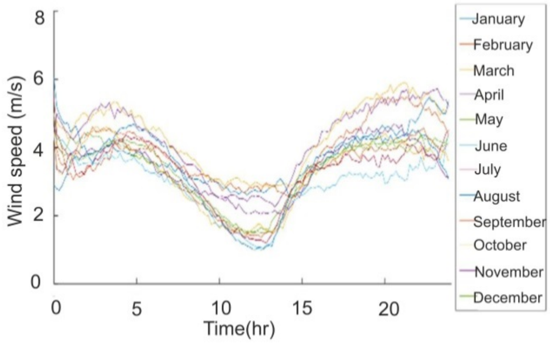

Fig. 3. Variation of wind speed per month

Figure 4 shows the variation of the wind speed during a typical year for each month according to the transition of time during the day. You can observe fluctuations of the wind speed according to Table 3. In the first months of the year, the wind speeds in midwinter tend to increase and these ones are staying until spring. In summer the wind speeds start to decrease and increase again in autumn. In the autumn-winter output the winds tend to decrease the speeds, however, these winds remain more constant.

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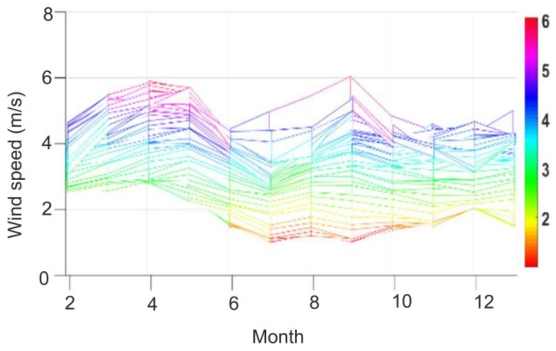


Fig. 4. Variation of wind speed per day month year

In Table 4, we can find disaggregated the maximum speed for each month and the ranges of peak hours in which these winds are presented. These ranges are classified according to the wind type.

Table 4. Average wind speeds, occurrence and denomination.

Month average	Speed (m/s)	Max. Speed Time (hour)	Denomination Min	Max
Januay	2.5 – 4.7	17:30– 22:30	Light Breeze 1.9 - 3.3	Moderate Breeze 5.3 -7.4
February	2.5 – 5.6	17:30- 24:00	Light Breeze 1.9 - 3.3	Moderate Breeze 5.3 -7.4
March	2.6 – 5.8	18:00- 23:30	Light Breeze 1.9 - 3.3	Moderate Breeze 5.3 -7.4
April	2.2 – 5.6	18:00- 23:00	Ligth air 0.6 – 1.7	Moderate Breeze 5.3 -7.4
May	1.4 – 4.5	21:30- 3:30	Ligth air 0.6 – 1.7	Gentle Breeze 3.4 -5.2
June	1.0 – 5.0	23:00- 1:00	Ligth air 0.6 – 1.7	Moderate Breeze 5.3 -7.4
July	1.2 – 5.5	23:30- 1:00	Ligth air 0.6 – 1.7	Light Breeze 5.3 -7.4
August	1 – 6.1	21:30- 2:00	Ligth air 0.6 – 1.7	Moderate Breeze 5.3 -7.4
September	1.3 – 4.8	21:00- 1:00	Ligth air 0.6 – 1.7	Gentle Breeze 3.4 -5.2
October	1.4 – 4.6	1:00- 5:00	Ligth air 0.6 – 1.7	Gentle Breeze 3.4 -5.2
November	2.0 – 4.7	19:00- 22:00	Ligth air 0.6 – 1.7	Gentle Breeze 3.4 -5.2
December	1.4 – 5.0	22:00- 1:00	Ligth air 0.6 – 1.7	Gentle Breeze 3.4 -5.2

The wind direction was determined using the compass rose by evaluating of wind direction annually and to each season. Figure 5 shows an annual wind rose where it is observed ranges of wind speed and wind direction according to Table 3. This figure indicates that the annual winds tend to be oriented towards the south-southwest (SSW).

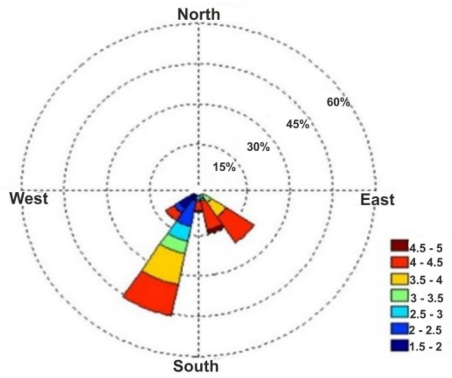
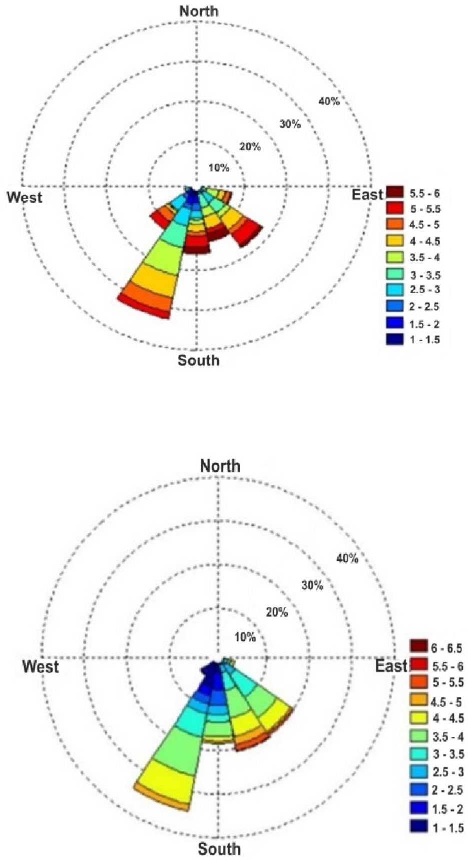


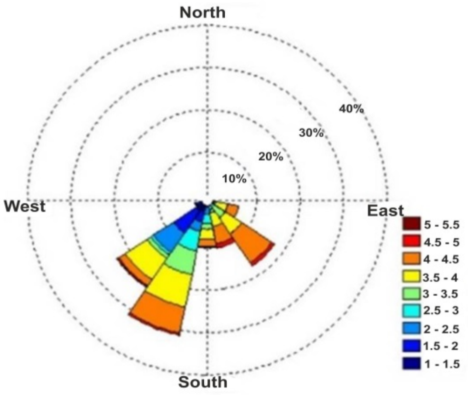
Fig. 5. Annual wind rose

In figure 6 the wind roses for every season are shown. It is observed that in seasons Spring (a), Summer (b) and Autumn (c) the orientation of the wind tends to be south southwest (SSW) presenting a behaviour similar to annual orientation (Fig.5) . While in winter season (d), the winds shown that the wind direction tends to be oriented towards the southwest (SW) and Southwest (SSW).

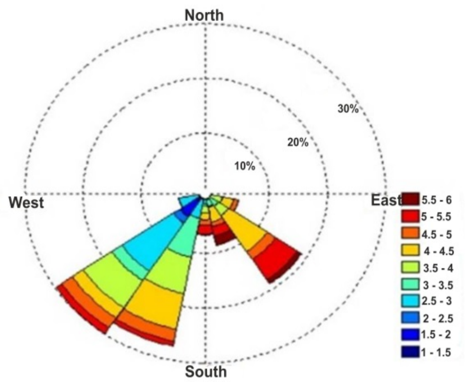


(a)

(b)



(c)



(d)

Fig. 6. Wind rose : Spring (a), Summer (b), Fall (c) e Winter (d).

In Table 5 the interpretation of orientation and repeatability percentage of winds are shown. Such repeatability percentage is exhibited by year according to Table 2, where it was designated a direction relative to the speeds and wind type classification.

Table 5. Average wind speeds, direction and denomination.

Season	Direction	Repeta-bility %	Spd. (m/s)	Denomination
Spring	SSW (202.5°)-SW (225°)	32%	5.0 - 5.5	Moderate Breeze (5.3 -7.4)
Summer	SSW (202.5°)-SW (225°)	35%	4.5 – 5.0	Gentle Breeze (3.5 – 5.2)
Fall	SSW (202.5°)-SW (225°)	31%	4.5 – 5.0	Gentle Breeze (3.5 – 5.2)
Winter	SW (225°)-WSW (247.5)	30%	5.5 – 6.0	Moderate Breeze (5.3 -7.4)
Anual	SSW (202.5°)-SW (225°)	45%	4.5 – 5.0	Gentle Breeze (3.5 – 5.2)

V.CONCLUTIONS

The results showed that the highest wind speeds occur during the nights in the spring season and the end of the summer season with a range of average speeds of 2.2 m / s to 6.1 m / s. In addition, average wind speeds prevailing throughout the year are 2.2 m / s to 4.1 m / s. These results suggest that the study area may be suitable for the generation of electrical or mechanical energy to small scale, with several small turbines connected together to generate enough electric power.

The Annual wind direction is south southwest (SSW) for seasons of spring, summer and autumn, however in winter the wind changes direction 20 ° to the southwest (SW) and then south southwest (SSW).

For the magnitude and direction of wind speed found, commercial turbines can be used working in wind regimes of 2.0 to 3.0 m / s. The study region seems to be very promising for the installation of wind-generating small-scale turbines.

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