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Technical note

Contribution to improving the modeling of wind and evaluation of the wind potential of the site of Lome: Problems of taking into account the frequency of calm winds

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A B S T R A C T

The purpose of this paper is to determine for the site of Lome, the best model that fits the frequency histogram of wind speeds to estimate with precision the amounts of recoverable wind energy. Our study was to characterize the wind potential of Lome using the approach of Hybrid Weibull distribution because of calm winds observed in the series of wind measurements of the site. To do this, two other traditional approaches often used to model the winds have been applied to this same site to better assess the results of applying the method of Hybrid Weibull. To this end, we first determined the statistical characteristics of measurements on the site and the methods used to model wind and evaluate the wind potential. We then proceeded to apply these methods to the site data, and finally an analysis of the results to confirm the validity of using the approach of hybrid Weibull distribution was made.

1. Introduction

Better installation site for wind power conversion systems should be selected taking into account several criteria such as maximum wind speed average, the daily and seasonal variations, turbulence levels, and extreme winds. For this reason the statistical studies are important to know the probabilities of these events. The wind as an energy source is extremely variable. Therefore finding a statistical model of the frequency distribution of wind speeds is necessary to predict the energy output of a wind energy conversion.

When wind measurements data is available on a given site, the information can be presented as a histogram. This may represent the variation of the relative frequency of wind speeds. If the speed intervals are dwindling, the limit of the histogram is a probability density function. Practically, obtaining the probability function of wind speed is obtained by approaching the histogram by a function [1]. In the case of wind speeds, a Gaussian or Rayleigh distribution function is not always adequate [2]. According to [3], a better solution is to use the Weibull distribution [4]. The probability density function of wind speed of a site can be approximated by a Weibull characteristic for measurements averaged from 1 to 30 min [5].

The wind atlas [6], was the first atlas to use the Weibull distribution. This is now a standard for the representation of the climatology of a wind farm [7]. This representation has the advantage of quickly determine the average annual production of a given wind generator with knowledge of the Weibull characteristic of the site and the power curve of the wind, as detailed in [7] and [8]. Reference [8] and [9] indicate that in regions where the frequencies of calm are relatively large, the classical Weibull distribution is unsuitable. In this case, they suggest treating the data with another solution. This solution is called the Hybrid Weibull distribution function. This is the solution we selected because we found that the frequency of calm winds in the series of wind data on the site of Lome is very important.

The application of this approach on the site of Lome and its comparison with standard techniques for estimating must first be assessed by the application of the distribution approaches such as Gaussian and Weibull distributions to the same site. This may allow us to confirm the validity of using the hybrid Weibull approach as the best solution in the modeling of wind and wind farm potential evaluation at the site of Lome.

2. Characteristics of data sets of wind speeds available on the site studied

2.1. Source of wind data

Our focus throughout this paper is to model the wind and assess the wind potential at the site of Lome with a more appropriate tool

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given the series of observed wind data. The series of wind data on the site of Lome were obtained through the meteorological database of the website http://weather.uwyo.edu/surface/meteogram/ [10]. Data are recorded every day by 1 h interval (this is averaged over 10 min before the hour) at a height of 10 m above the ground. The data sheet provided by [Wyoming] (an example is shown in Table 1) includes, respectively for each record: the name of the site (STN), the recording time (date and time) (TIME), the atmospheric pressure (ALTM), the ambient temperature (TMP), the temperature of the dew (DEW), the relative humidity (RH), the wind direction (DIR), the wind speed (SPD), the Visibility (VIS) and the nature of clouds (cloud). It should be noted that the point of measurement of these weather data in Lome on the website [10] is located at the airport in Lome. The data collected for Lome covers the period of July 2004–July 2006. In Table 1, we are only interested in recording time (TIME) and wind speed (SPD) columns for our current work.

2.2. Statistical parameters of wind speeds of the site

To determine the statistical parameters, we represent (Fig. 1) the data of hourly wind speeds observed on the site of Lome in the form of a histogram. The analysis of this histogram clearly reveals that wind speeds around 0 m per second (Calms), are important (12.61%). We represent in Table 2 the statistical characteristics obtained after the processing of the study site data.

3. Presentation of the methods used to model wind and wind potential evaluation

3.1. Normal distribution or laplace-gauss

The normal distribution is very important in practice because it is satisfactory in the study of many phenomena. Furthermore, this law is technically very convenient to use because it depends on two parameters (mean and standard deviation) which are relatively easy to determine [11]. The series of average speeds can be generated using an independent sequence of random numbers from the normal distribution. The probability function of the Normal distribution is given by Equation (1):

$$f(v) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left[-(v-\mu)^2/2\sigma^2\right] \tag{1}$$

where: v variable (in our case, v is the hourly average wind speed); μ the average of the hourly wind speed data, σ the standard deviation of hourly data of wind speed.

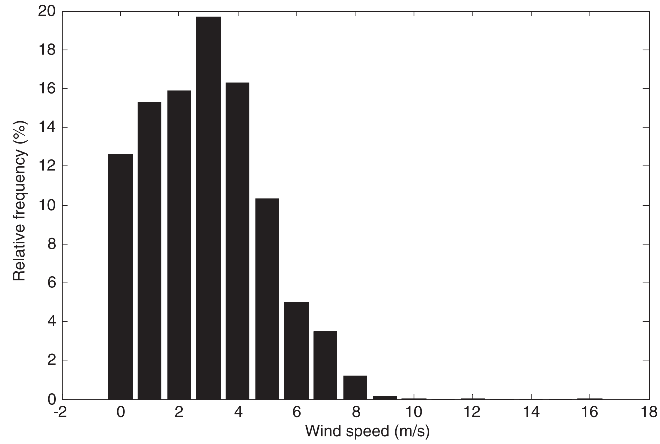

Fig. 1. Histogram of speed zones on the site of Lome.

3.2. Classical Weibull distribution

The Weibull distribution is a special case of the generalized Gamma distribution. There are Weibull distributions with two and three parameters. In order to comply with the standards of the wind industry, we will use the Weibull function with two parameters as shown by [7,12,13]. The mathematical expression of the Weibull distribution with two parameters is:

$$f(v) = \left(\frac{K}{C}\right)\left(\frac{v}{C}\right)^{K-1}\exp\left[-\left(\frac{v}{C}\right)^{K}\right] \tag{2}$$

where: $f(v)$ is the frequency of occurrence of wind speed, v is the wind speed in m/s; C the scale factor (size of a speed); K the shape factor (dimensionless) characterizing the Skewness of the distribution.

The values of C and K Weibull parameters are determined by the method of maximum-likelihood estimation that requires solving the Equations (3) and (4).

$$K = \left[\left[\frac{\sum_i n_i v_i \ln(v_i)}{\sum n_i v_i}\right] - \left[\frac{\sum_i n_i \ln(v_i)}{N}\right]\right]^{-1} \tag{3}$$

$$C = \left[\frac{\sum_i n_i v_i}{N}\right]^{1/K} \tag{4}$$

Table 1
Presentation of a form of the website data [10] forming the source of data.

Observations for LOME TOKOIN MIL, Togo (DXXX)												
1300Z 5 Jul 2004–1700Z 5 Jul 2004												
STN	TIME DD/HHMM	ALTM hPa	TMP °C	DEW °C	RH %	DIR deg	SPD m/s	VIS km	CLOUDS			
DXXX	26/1500	1009.2	30	24	70	200	6	10	FEW020	BKN250		
DXXX	26/1400	1010.2	31	24	66	190	7	10	FEW020	BKN250		
DXXX	26/1300	1010.8	31	25	70	200	6	10	FEW020	BKN250		
DXXX	26/1200	1011.9	31	26	75	200	6	10	SCT020	BKN250		
DXXX	26/1100	1012.9	31	25	70	210	5	10	SCT016	BKN250		
DXXX	26/1000	1012.9	30	25	75	210	6	10	BKN015	BKN230		
DXXX	26/0900	1013.9	29	25	79	210	5	10	BKN013	BKN230		
DXXX	26/0830	1012.9	29	26	84	220	4	10	BKN013	BKN230		
DXXX	26/0800	1012.9	28	25	84	220	3	8	SCT012	BKN230		
DXXX	26/0730	1011.9	27	25	89	0	0	7	FEW010	BKN230		
DXXX	26/0630	1011.9	26	23	84	0	0	3	FEW010	BKN050	BKN230	F
DXXX	26/0600	1010.8	26	24	89	0	0	4	FEW010	BKN050	BKN230	F
DXXX	26/0530	1010.8	26	23	84	0	0	6	SCT010	BKN100		