Available online at www.iseec2012.com

I-SEEC 2012

Proceeding - Science and Engineering (2013) 302–308

Proceeding
Science and Engineering

www.iseec2012.com

Science and Engineering Symposium
4th International Science, Social Science, Engineering and Energy Conference 2012

Analysis of the Burr type XII distribution for estimation of wind speed distributions

I. Usta[a,*] , Y. Mert Kantar[a]

[a]*Department of Statistics, Faculty of Science, Anadolu University, Eskisehir 26470, Turkey*

Abstract

The wind speed distribution is the basis for the assessment of wind energy potential of specified region. Thus, the proper specification of the wind speed distribution is of great importance. Several statistical distributions have been used for the description of the wind speed distribution. The Weibull distribution is the most popular. However, the Weibull distribution does not show good performance for all wind types encountered in nature. In this study, we introduce the Burr type XII distribution as a new alternative wind speed distribution. Comparisons of the Burr type XII distribution and Weibull distribution on wind speed data are conducted. The analyses results indicate that the Burr type XII distribution can show better results than the Weibull distribution for wind speed data. Thus, the Burr type XII can be used as an alternative distribution to model wind speed data and to estimate wind power potential.

Selection and/or peer-review under responsibility of Faculty of Science and Technology, Kasem Bundit University, Bangkok.

Keywords: Wind speed, Weibull distribution, Burr type XII, model selection criteria

1. Introduction

The proper determination of wind speed probability distribution for a certain location is crucial in determining potential of wind energy. In the wind energy literature, the Weibull distribution has been commonly used, accepted and recommended distribution for the wind speed data [1-7]. For this reason, for many locations over the world of different topographies, the Weibull distribution has been used to model wind speed.

The probability density function (pdf) of the Weibull distribution with two parameters, i.e., $f_{WD}(v)$ is given as follows:

$$f_{WD}(v) = (\frac{\theta_2}{\theta_1})(\frac{v}{\theta_1})^{\theta_2 - 1} \exp(-(\frac{v}{\theta_1})^{\theta_2}), \; v > 0 \tag{1}$$

where θ_1 and θ_2 are the scale and shape parameters of the Weibull distributions, respectively.

* Corresponding author. *E-mail address:* iusta@anadolu.edu.tr

It is known that when the shape parameter of the Weibull distribution is assumed to be equal to 2, the Rayleigh distribution, one of the known-wind speed distributions, is obtained.

The pdf of the Rayleigh distribution is presented as follows:

$$f_{RD}(v) = (\frac{2}{\theta_1})(\frac{v}{\theta_1})\exp(-(\frac{v}{\theta_1})^2),\ v > 0, \quad (2)$$

Nomenclature

v	Wind speed (m/s)
v_i	i*th* observed wind speed data
θ_1	Scale parameter of the distribution
θ_2	First shape parameter of the distribution
θ_3	Second shape parameter of the distribution
$f_{WD}(v)$	Weibull probability density function (pdf)
$f_{RD}(v)$	Rayleigh probability density function (pdf)
$f_{BXII}(v)$	Burr type XII probability density function (pdf)
Pdd	Wind power density distribution
R^2	Coefficient of determination
RMSE	Root mean square error
χ^2	Chi-square
x_j	jth observed probability
y_j	jth predicted probability calculated from a special distribution
z_j	jth computed value from the correlation equation for the same value of x_i
N	number of all observed wind speed data
n	the number of parameters or the number of constraints.

Despite the widespread use of the Weibull distribution, the Weibull distribution does not show good performance for all wind types encountered in nature such as low and high wind speed [8-10]. Hence, in recent years, new families of distributions as an alternative to the Weibull distribution have been proposed to model the wind speed. The purpose of this paper is to introduce the Burr type XII as a new wind speed distribution. As a second purpose, we compare the Burr type XII with the Weibull distribution on wind speed data in terms of various criteria. We find that the Burr type XII shows better performance than the Weibull distribution in estimating wind speed distribution and therefore this new distribution can be used to estimate wind power density distribution (Pdd).

2. The Burr type XII distribution

The reason we propose Burr type XII distribution as a reasonable wind speed distribution is that the Weibull distribution emerges as a limiting case of the Burr type XII distribution. Also, it is known that the Burr type XII is flexible and effective distribution when modeling statistical data.

The pdf and cdf of the Burr type XII distribution are respectively given as follows:

$$f_{BXII}(v) = \frac{\theta_2\theta_3(\frac{v}{\theta_1})^{\theta_2-1}}{\theta_1(1+(\frac{x}{\theta_1})^{\theta_2})^{\theta_3+1}}, \; v>0 \tag{3}$$

$$F_{BXII}(v) = 1-(1+(\frac{x}{\theta_1})^{\theta_2})^{-\theta_3} \tag{4}$$

where θ_1 is the scale parameter, θ_2 and θ_3 are shape parameters of the Burr type XII distributions, respectively.

3. Model Selection Criteria

In order to show the performance of the Burr type XII relative to the Weibull and Rayleigh distributions, root mean square error (*RMSE*), Chi-square (χ^2) and correlation coefficient (R^2) as model selection criteria are used. These criteria, given as following equations, are based on distance between the theoretical distributions and the corresponding experimental frequencies distribution.

$$R^2 = 1-\frac{\sum_{i=1}^{N}(y_i-x_i)^2}{\sum_{i=1}^{N}(y_i-z_i)^2}, \tag{5}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(y_i-x_i)^2}{N}}, \tag{6}$$

$$\chi^2 = \frac{\sum_{i=1}^{N}(y_i-x_i)^2}{N-n}. \tag{7}$$

The distribution with smaller *RMSE* and χ^2 measure values are to be preferred to those with larger values and the best distribution can be determined according to the highest values R^2.

4. Results and discussion

In order to evaluate the suitability of the Burr type XII distribution for wind speed data, some analyses have been made based on monthly wind speed data measured in Aliaga, Turkey. The monthly wind speed data were recorded on July, 2008 at a height of 10 m and 30 m. The performance of the Burr type XII distribution relative to the Weibull and Rayleigh distributions is evaluated in terms of R^2, RMSE and χ^2. Results for monthly wind speed data are given in Table 1. Also, the graphs of the pdfs corresponding to the Burr type XII, Weibull and Rayleigh distributions are presented in Fig.1 and Fig.2 for a height of 10 m and 30 m, respectively. Moreover, the wind power density distributions corresponding to the Burr type XII, Weibull and Rayleigh distributions are given in Fig. 3 and Fig.4.

Table 1. Estimates of parameters of the Weibull, Rayleigh and Burr type XII and the model selection criteria for monthly wind speed data measured in Aliağa, Turkey.

	Models	θ_1	θ_2	θ_3		R^2	*RMSE*	χ^2
	f_{WD}	10.6652	4.1959	--		0.9414	0.0124	0.000180
10 m	f_{RD}	10.0327	--	--		0.3273	0.0440	0.002089
	f_{BXII}	38.7230	4.2046	235.7700		0.9439	0.0121	0.000179
	f_{WD}	12.4838	4.3593	--		0.9616	0.0089	0.000091
30 m	f_{RD}	11.7403	--	--		0.2587	0.0408	0.001774
	f_{BXII}	23.6710	4.4984	19.5270		0.9702	0.0081	0.000081

As seen in Table 1, according to the R^2 criterion, the Burr type XII outperform over the Weibull and Rayleigh distributions for monthly wind speed data measured at 10 m and 30 m. These results are supported by the *RMSE* and χ^2 statistics.

The fitted pdfs and the histogram of monthly wind speed data measured at 10 m and 30 m are shown in Fig. 1 and Fig. 2, respectively. As seen in these figures, the Burr type XII exhibit better fit to wind data and particularly a peak of wind data than the Rayleigh. Thus, it can be concluded that the Burr XII is flexible enough to adapt to wind speed data as well as the Weibull distribution. On the other hand, Fig. 3 and Fig. 4 demonstrate the wind Pdds based on the Burr XII, Weibull, Rayleigh and the experimental wind Pdds as a histogram. It can be deduced from these figures that wind Pdds based on the Burr XII provide a good fit for the considered wind speed data.

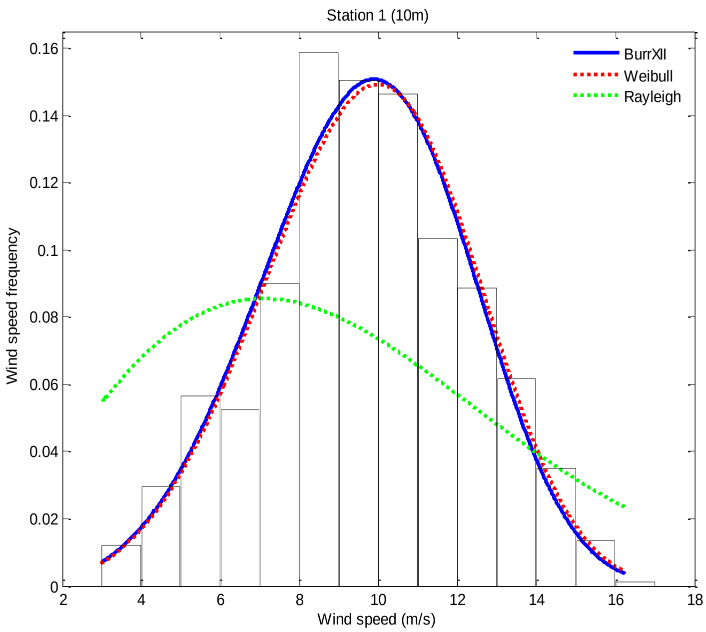

Fig. 1. The histogram and pdf graphs of Weibull, Rayleigh and Burr XII distribution for wind speed data measured at a height of 10 m

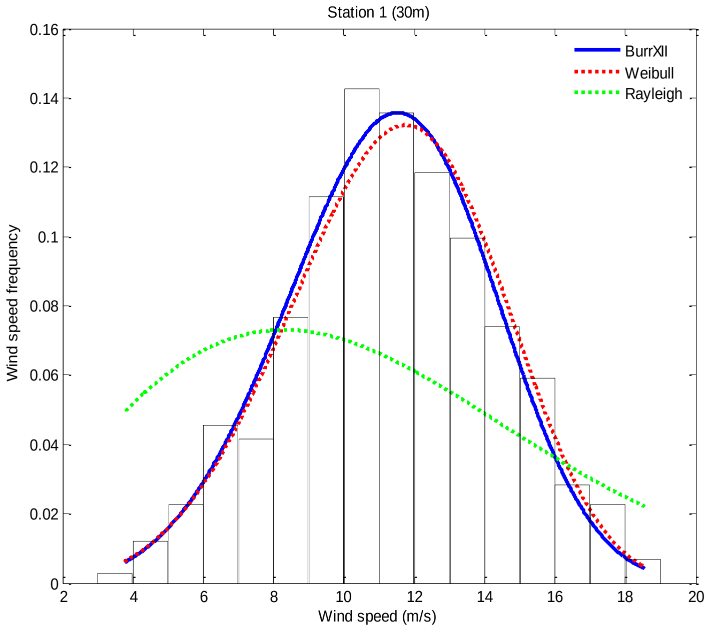

Fig. 2. The histogram and pdf graphs of Weibull, Rayleigh and Burr XII distribution for wind speed data measured at a height of 30 m

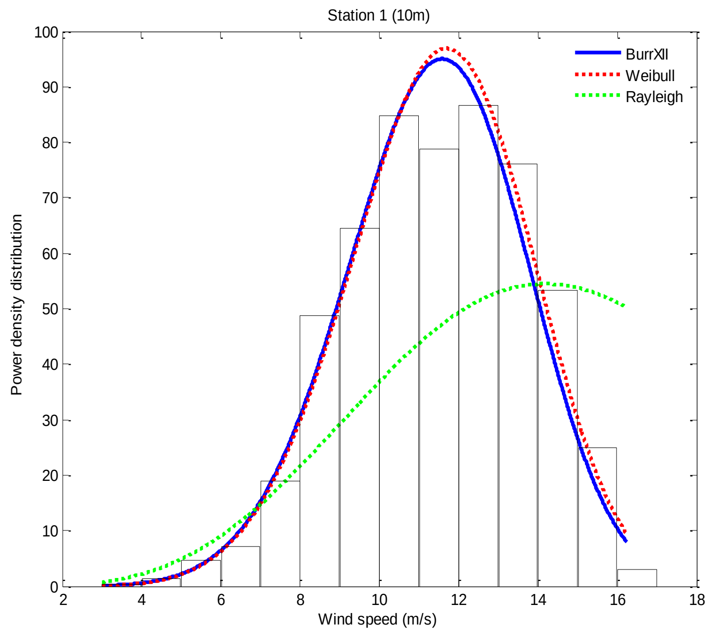

Fig. 3. The histogram and Wind power density graphs of Weibull, Rayleigh and Burr XII distribution for monthly wind speed data measured at a height of 10 m

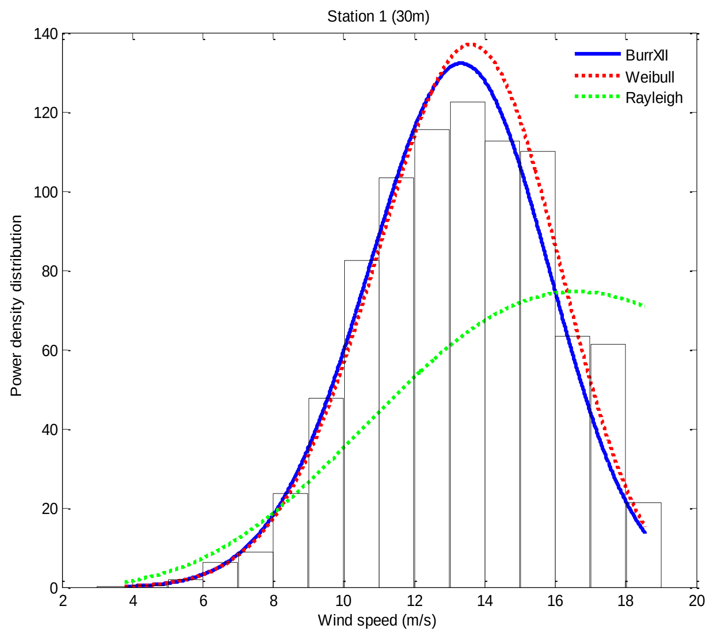

Fig. 4. The histogram and Wind power density graphs of Weibull, Rayleigh and Burr XII distribution for wind speed data measured at a height of 30 m

The result of can be summarized as follows:

1. Burr type XII distribution is presented as alternative wind speed distribution.
2. Comparisons based on the monthly wind speed data measured at Aliaga in Turkey are made to evaluate performance of the Burr type XII relative to the Weibull and Rayleigh by using some criteria.
3. It is shown that Burr type XII provides the best fit to the considered wind speed data. Moreover, these results are supported by the graphical illustration of the considered distributions.
4. These results are also supported by wind power density distributions corresponding to Burr XII.
5. Moreover, we will pursue this study by expanding analyses on wind speed data measured in different region.

References

[1] Ahmed AS. Wind energy as a potential generation source at Ras Benas, Egypt. Renew Sustain Energy Rev 2010;14(8):2167–73.
[2] J Weisser D. A wind energy analysis of Grenada: an estimation using the'Weibull' density function. Renew Energy 2003;28:1803–12.
[3] Akdag S, Guler O. Wind characteristics analyses and determination of appropriate wind turbine for Amasra Black Sea region, Turkey. Int J Green Energy 2010;7(4):422–33.
[4] Kantar YM, Senoglu B. A comparative study for the location and scale parameters of the Weibull distribution with given shape parameter. Comput Geosci 2008;34:1900–9.
[5] Seguro JV, Lambert TW. Modern estimation of the parameters of the Weibull probability density distribution. J Wind Eng Ind Aerodyn 2000;85:75–84.
[6]Akdag S, Dinler A. A new method to estimate Weibull parameters for wind energy applications. Energy Convers Manage 2009;50:1761–6.
[7] Akdag S, Dinler A. A new method to estimate Weibull parameters for wind energy applications. Energy Convers Manage 2009;50:1761–6.
[8] Shamilov A, Kantar YM, Usta I. Use of MinMaxEnt distributions defined on basis of MaxEnt method in wind power study. Energy Convers Manage 2008;49:660–77.

[9] Kantar YM, Usta I. Analysis of wind speed distributions: wind distribution function derived from minimum cross entropy principles as better alternative to Weibull function. Energy Convers Manage 2008;49:962–73.

[10] Usta I, Kantar YM. Analysis of some flexible families of distributions for estimation of wind speed distributions. Applied Energy 2012;89: 355–367.