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Analysis of wind energy conversion system using Weibull distribution

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Abstract

In this study, the wind speed data has been statistically analyzed using Weibull distribution to find out wind energy conversion characteristics of Hatiya Island in Bangladesh. Two important parameters like Weibull shape factor "k" and Weibull scale factor "c" have been calculated by four methods. The probability density function f(x), cumulative distribution function or Weibull function F(x) have been used to describe the best wind distribution between observed and theoretically calculated data. There are six statistical tools used to analyze the goodness of curve fittings and precisely rank the methods. For a selected month the Weibull shape factor was found to be very close to the Raleigh function k=2 indicating the characteristics of wind wave are regular and uniform. For the other period 'k' varies between 1.99 to 3.31 and 'c' between 2.83 to 7.25 m/sec. The study found that more than 58% of the total hours in a year have wind speed above 6.0 m/s in Hatiya, therefore this site has enough available power to drive a small wind turbine for electricity generation. The proposed methodology can be used in any windy site to easily identify the potentiality of wind power.

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Keywords: Wind speed; Weibull distribution; Weibull function; available energy; wind turbine.

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1. Introduction

In planning of offshore wind farm, analyzed the probability distributions for short term wind speeds. Short-term wind speeds play a central role in estimating various engineering parameters, such as power output, extreme wind load, and fatigue load [1, 2].

Nomenclature

v	Wind speed in m/sec.
k	Weibull shape factor.
c	Weibull scale factor in m/sec.
$F(x)$	Cumulative distribution function.
$f(x)$	Probability density function.
$\bar{v}$	Mean wind speed, m/sec.
σ	Standard deviation.
Γ	Gamma function.
ε_{yi}	Error.
W_{vi}	Observed frequency of wind speed.

In general, wind power prediction methods are categorized into two groups: physical and statistical. The first one implies physical considerations such as topography, terrains, local temperature and pressure to estimate the wind field more accurately and, subsequently, the energy potential [3]. The later one, on the other hand, use statistical models in order to establish the relationship between power and other variables as well as their historical and forecasted values [4, 5].Weibull distribution provides better fit to probability distributions compared to Rayleigh model and analyzes the wind speed data by using statistical distributions [6, 7]. The Weibull distribution (named after the Swedish physicist W. Weibull, who applied it when studying material strength in tension and fatigue in the 1930s) provides a close approximation to the probability laws of many natural phenomena. It has been used to represent wind speed distributions for application in wind loads studies for some time [8, 9]. For more than half a century the Weibull distribution has attracted the attention of statisticians working on theory and methods as well as various fields of statistics [10]. The research related to wind energy in Bangladesh originated as early as in 1979 in collaboration with Free University of Brussels (FUB), Belgium. In this work, only two islands (Hatiya and Sandwip) were selected due to its geographical location and by considering other factors such as potential of wind power, difficulties of fuel transportation by road etc. Hatiya is situated between $22°26'$ north latitude to $91°6'$ east longitude and Sandwip is situated in between $22°29'$ north latitude to $91°26'$ east longitude. These two islands are separated by Bangla-channel and the greatest Bay of Bengal Sea. So, the selected sites have more potential of wind energy to develop the country.

2. Outline of methodology

There are several methods by which Weibull shape factor "*k"* andscale factor "*c"* can be determined. In this work, there are four popular methods have been used to determine Weibull parameters, these are: a) Graphical method, b) Method of moments (MOM), c) Empirical method and d) Equivalent energy method. The Weibull distribution function, which is a three-parameter function, but for wind speed, it can be expressed mathematically in two parameter model as follows [11].

$$f(v) = \frac{dF(v)}{dv} = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \times e^{-\left(\frac{v}{c}\right)^{k}} \quad (1)$$