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# Estimation of wind power density at a wind farm site located in Western Rajasthan region of India

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**Abstract**

Wind power density is an important parameter for the potential estimation of a wind farm and is used to compare different sites. This paper estimates wind power density of Soda site located at Western Rajasthan in India. Modified Maximum Likelihood, Empirical, and Graphical methods are used for estimating Weibull distribution parameters, which are used for calculating wind power density. The calculated wind power density is then compared with actual measured values for validation. The results obtained using Empirical method shows better agreement with the measured data of wind power density.


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*Keywords:* Weibull distribution; site selection; wind farm; wind power density; wind turbine.

## 1. Introduction

Wind power density (WPD) of a site helps in the comparison and selection of best-suited sites for the wind turbines. Turbines that are installed at sites having higher WPD usually generate higher electric energy. WPD of Soda site located in the Western Rajasthan region of India is estimated in this paper. Weibull distribution parameters of Soda site are estimated using Modified Maximum Likelihood, Empirical, and Graphical methods, which are used for calculating the WPD.

This paper is organized as follows: Section 2 explains the statistical analysis of wind data, section 3 discusses the three different methods of estimating Weibull distribution parameters, section 4 explains the method of estimating

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WPD from Weibull parameters of the site, section 5 shows the results of WPD estimations at Soda site in Jaisalmer district of Rajasthan, and section 6 draws the conclusions of analysis.

## 2. Wind data analysis using statistics

Wind speed probability distribution function gives the probability of occurrence for a particular wind speed at a site, depending on the location parameters [1]. Weibull probability distribution function $f(v)$ is expressed as [2]:

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} e^{-(v/c)^k} \tag{1}$$

where $v$ is the wind speed, $k$ is the shape parameter, and $c$ is the scale parameter.

## 3. Estimation of Weibull distribution parameters

Rocha et al. [3] explained seven numerical methods for estimating the scale and shape parameters of Weibull probability distribution function. This paper uses three methods for estimating the Weibull parameters.

### *3.1. Modified Maximum Likelihood (MML) method*

It is an iterative method and uses wind speed frequency distribution of the site. Rocha et al. [3] explained that in this method, the Weibull distribution shape and scale parameters are calculated by using the expressions

$$k = \left[ \frac{\sum_{i=1}^{n} v_i^k \ln(v_i) f(v_i)}{\sum_{i=1}^{n} v_i^k f(v_i)} - \frac{\sum_{i=1}^{n} \ln(v_i) f(v_i)}{f(v \geq 0)} \right]^{-1} \tag{2}$$

$$c = \left( \frac{1}{f(v \geq 0)} \sum_{i=1}^{n} v_i^k f(v_i) \right)^{\frac{1}{k}} \tag{3}$$

where the number of bins is $n$, frequency of wind speed occurrence in bin $i$ is $f(v_i)$, wind speed at $i$th bin midpoint is $v_i$, and the probability of wind speed $\geq 0$ is $f(v \geq 0)$.

### *3.2. Empirical method (EM)*

Manwell et al. [1] and Rocha et al. [3] estimated the Weibull parameters from the expressions

$$k = (\sigma/\bar{v})^{-1.086} \tag{4}$$

$$c = \left(\bar{v}/\Gamma(1+1/k)\right) \tag{5}$$

where $\bar{v}$ is mean wind speed, $\sigma$ is standard deviation of wind speed, and $\Gamma$ is gamma function defined by integral