WIND ENERGY EVALUATION FOR POWER GENERATION IN SELECTED DISTRICTS OF KERALA

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In place of fossil fuels, humans are looking for clean and renewable source of energy. Among all renewable energy sources wind energy is most widely used and is gaining acceptance day by day. The four districts of Kerala: Thiruvananthapuram, Alappuzha, Kozhikode and Kochi were selected to evaluate the wind power potential for electricity production. The assessment was carried out using the monthly average wind speed statistics of 22 years period from the RETScreen climate database at an altitude of 10m from ground. The monthly average wind speed data were subjected to two parameters Weibull distribution along with additional statistical methods. The results indicate that small-scale wind turbine can be used to extract energy from the low speed wind, preferably at a height above 10m from the ground.

Keywords: Fuel, Wind energy, Kerala, Average wind speed, RETScreen, Weibull probability distribution.

1. Introduction

A developing country like India, is going through a phase of modernization and infrastructure development, which require ample power supply. In present scenario, India is mainly dependent upon fossil fuels for power generation and burning of these causes air pollution, water and land degradation. Due to limited resource of fossil fuel and its adverse effect on environment, the use of environment friendly renewable energy based power generation has gained wide acceptance across the globe. Among various renewable energy sources like biomass, geothermal energy, solar energy, wind energy, ocean thermal energy etc. wind energy is most widely used and is gaining acceptance day by day throughout the globe [1]. With the help of wind turbine, wind energy is converted into electricity which is subsequently used in various activities [2]. The prime focus of the analysis is to evaluate the availability of wind power for electricity production at different locations in the state of Kerala [3-6]. Kerala mainly produces electricity on four fonts - hydro, thermal, wind and solar. Of these, wind and solar power generations make only borderline contributions [7].

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Overall mounted capacity of power in the State as in March 2016 is 2880.20 MW. Of which wind energy contributed 43.27 MW. Agency for Non-Conventional Energy and Rural Technology(ANERT) conducted a comprehensive study of the wind energy potential of Kerala and rated Kerala to be blessed with high wind potential [8]. The wind energy potential is not evenly distributed all over the state of Kerala. To have better idea about the wind energy distribution across the state a site-by-site calculation of wind power density and other parameters are essential [9-13]. Due to rapidly rising demand of power in Kerala, an alternative renewable source of energy is required to lower the dependence on limited fossil fuel resource. This will not only reduce the pollution level but also cut the gap between demand and supply of power requirement [14-15]. The four districts of Kerala – Thiruvananthapuram, Alappuzha, Kozhikode and Kochi are investigated for evaluating the availability of wind energy for electricity generation.

Nomenclature:

u: Wind speed(ms^{-1}).
u_m: Average wind speed (ms^{-1}).
f(u): Probability density function.
F(u): Cumulative density function.
K: Weibull shape parameter (dimensionless).
σ: Standard deviation.
Γ: Gamma function.
u_{mp}: Most probable wind speed (ms^{-1}).
n: Total number of data.
C: Weibull scale parameter (ms^{-1}).
P(u): Wind power density (Wm^{-2}).
ρ: Density of air (kgm^{-3}).
$u_{Emax.}$: Maximum energy carrying wind speed (ms^{-1}).

2. Methodology

The wind energy potential of four district of Kerala namely Thiruvananthapuram, Alappuzha, Kozhikode And Kochi are examined by means of the average wind speed statistics of 22 years. duration (January 1983 to December 2004) from the RETScreen climate database at an altitude of 10m from ground [16]. Table 1 depicts the data like location, elevation and air density of the selected districts for evaluation of wind power potential. The four districts of Kerala namely Thiruvananthapuram, Alappuzha, Kozhikode and Kochi are selected as they are developing at a rapid rate and power prerequisite in future will not be fulfilled merely by conventional fossil fuel based power stations.

2.1 Weibull Distribution

Among the various statistical distributions available, the Weibull probability distribution has remained to be most consistent and hence employed for analyzing wind energy potential of four district of Kerala – Thiruvananthapuram, Alappuzha, Kozhikode and Kochi. Also, the two parameter Weibull statistical distribution is found to be more exact and realistic than corresponding three parameters Weibull distribution [17-18]. The monthly average wind speed data were subjected to two parameters Weibull distribution along with additional statistical methods [19-20]. The probability density function and cumulative density function are represented by equations (1) and (2) separately.

$$f(u)=\left(\frac{K}{C}\right)\left(\frac{u}{C}\right)^{K-1}\exp.\left[-\left(\frac{u}{C}\right)^{K}\right] \quad (1)$$

$$F(u)=1-\exp.\left[-\left(\frac{u}{C}\right)^{K}\right] \quad (2)$$

Table 1

Information of districts under consideration

District	Latitude (N)	Longitude (E)	Elevation (m)	Air Density (kgm^{-3})
Thiruvananthapuram	8.5	77.0	64	1.149
Alappuzha	9.5	76.3	82	1.145
Kozhikode	11.3	75.8	5	1.123
Kochi	10.0	76.2	235	1.131

The various notations used have their usual meanings like K(dimensionless) and C(m/s) being Weibull shape and scale parameter whereas f(u) and F(u) are probability and cumulative density function respectively.

The average (u_m) and variances (σ^2) of wind speed data of four districts are calculated from the equations (3) and (4) respectively.

$$u_m=\frac{1}{n}\sum_{i=1}^{n} u_i \quad (3)$$

$$\sigma^2=\frac{1}{n-1}\sum_{i=1}^{n}(u_i-u_m)^2 \quad (4)$$

Here the notation i is used to represent the monthly wind speed data whereas n is the entire number of data used for individual year.

The average (u_m) and standard deviation (σ) of wind speed data are used to calculate the two parameters of Weibull distribution namely shape (K) and scale (C) parameter according to equations (5) and (6) respectively.

$$K=\left(\frac{\sigma}{u_m}\right)^{-1.086} \quad (5)$$

$$C=\frac{u_m}{\Gamma\left(1+\frac{1}{K}\right)} \quad (6)$$

The notation u_m is used to represent average wind speed (m/s), σ represent standard deviation of wind speed data and Γ is the gamma function.

The values of most probable wind speed (u_{mp}) and maximum energy carrying wind speed ($u_{Emax.}$) predicts the wind energy potential of that region. The relationship between most probable wind speed and two Weibull parameters (K and C) is represented by equation (7) while equation (8) represents the relationship between maximum energy carrying wind speed and two Weibull parameters (K and C) respectively.

$$u_{mp}=C\left(\frac{K-1}{K}\right)^{1/K} \quad (7)$$

$$u_{Emax.}=C\left(\frac{K+2}{K}\right)^{1/K} \quad (8)$$

2.2 Wind Power Density

In comparison to average wind speed data available of any region, the value of wind power density gives a better idea about the potential of wind power available for electricity production [21]. The value of wind power density, P(u) at any location can be calculated in terms of two Weibull parameters (K and C) according to equation (9) mentioned below.

$$P(u)=\frac{1}{2}\rho c^3\left(1+\frac{3}{k}\right) \quad (9)$$

Where, ρ is the density of air expressed in (kg/m^3).

3. Result and Discussion

The monthly and annual average wind speed data of 22 years period (January 1983 to December 2004) obtained from the RETScreen climate database at an altitude of 10m from ground for four districts of Kerala namely Thiruvananthapuram, Alappuzha, Kozhikode and Kochi are revealed in Table 2. The comparison among four districts of Kerala in terms of monthly average wind speed data is shown in figure 1.

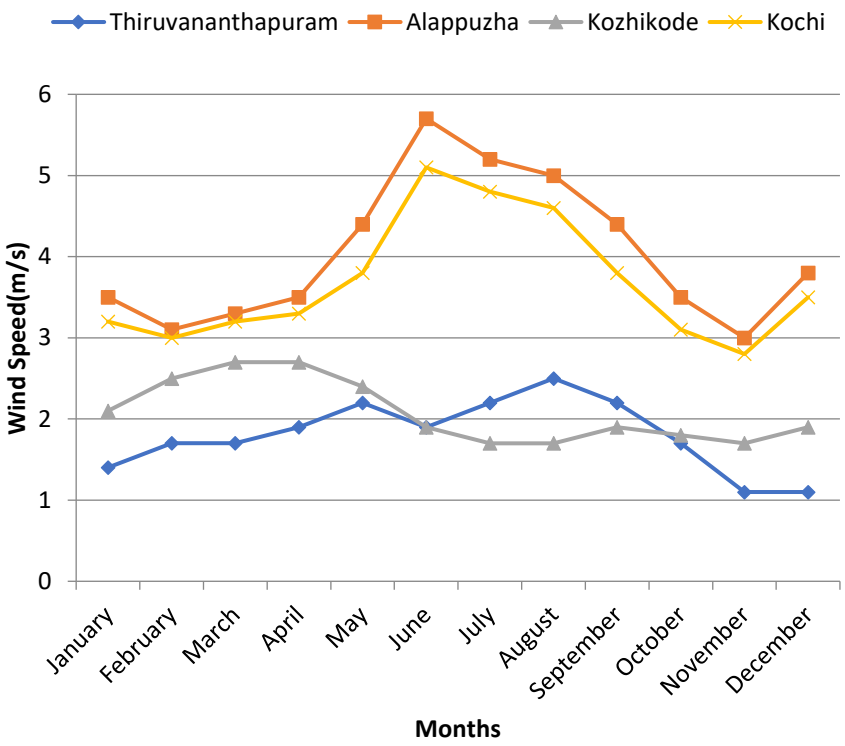

Fig. 1. Monthly Average Wind Speed Variations of the Four Districts

It clearly shows that Alappuzha surpasses the other three districts in terms of monthly normal wind energy available. The monthly average wind speed value lies between 1.1 to 2.5 m/s for Thiruvananthapuram, 3.0 to 5.7 m/s for Alappuzha, 1.7 to 2.7 m/s for Kozhikode and 2.8 to 5.1 m/s for Kochi throughout a year. Figure 2 to 5 shows the monthly variation of wind speed for four districts of Kerala and it clearly indicates that wind speed is not consistent throughout a year for any district. Also, it shows that the months during which wind speed is higher or lower than the yearly average wind speed for the four districts of Kerala. The figures predict the months for maximum and minimum wind power potential for the selected districts of Kerala. The various statistical and Weibull parameters after calculation are shown in table 3.

Table 2

Average wind speed data throughout the year for four Districts.

Month	Mean Wind Speed(m/s)			
	Thiruvananthapuram	Alappuzha	Kozhikode	Kochi
Jan.	1.4	3.5	2.1	3.2
Feb.	1.7	3.1	2.5	3.0
Mar.	1.7	3.3	2.7	3.2
Apr.	1.9	3.5	2.7	3.3
May	2.2	4.4	2.4	3.8
Jun	1.9	5.7	1.9	5.1
Jul.	2.2	5.2	1.7	4.8
Aug.	2.5	5.0	1.7	4.6
Sep.	2.2	4.4	1.9	3.8
Oct.	1.7	3.5	1.8	3.1
Nov.	1.1	3.0	1.7	2.8
Dec.	1.1	3.8	1.9	3.5
Annual	1.8	4.0	2.1	3.7

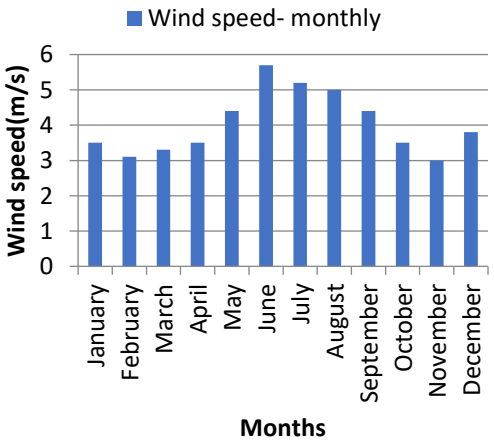

Fig. 2. Monthly Vs yearly average wind speed for Alappuzha

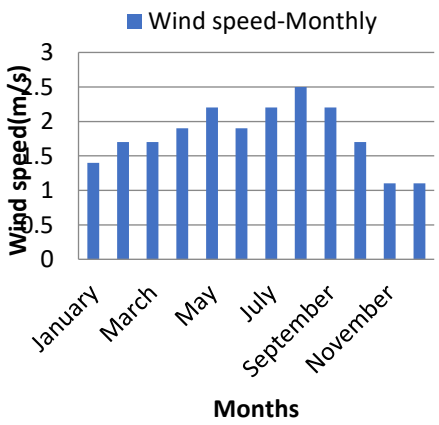

Fig. 3. Monthly Vs yearly average wind speed for Thiruvananthapuram

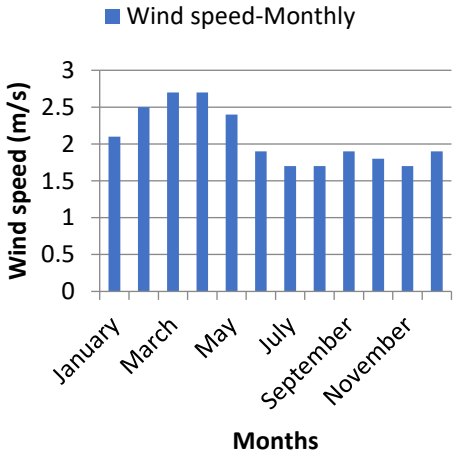

Fig. 4. Monthly Vs yearly average wind speed for Kozhikode

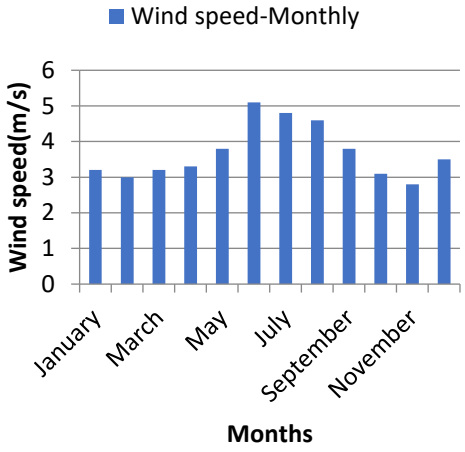

Fig. 5. Monthly Vs yearly average wind speed for Kochi

The shape parameter (K) of Weibull distribution are found to lie between $4.58 \leq K \leq 6.25$ whereas the scale parameter (C) of Weibull distribution lie between $1.97 \leq C \leq 4.35$. The two Weibull parameters (K and C) calculated for four districts of Kerala are depicted in figure 6.

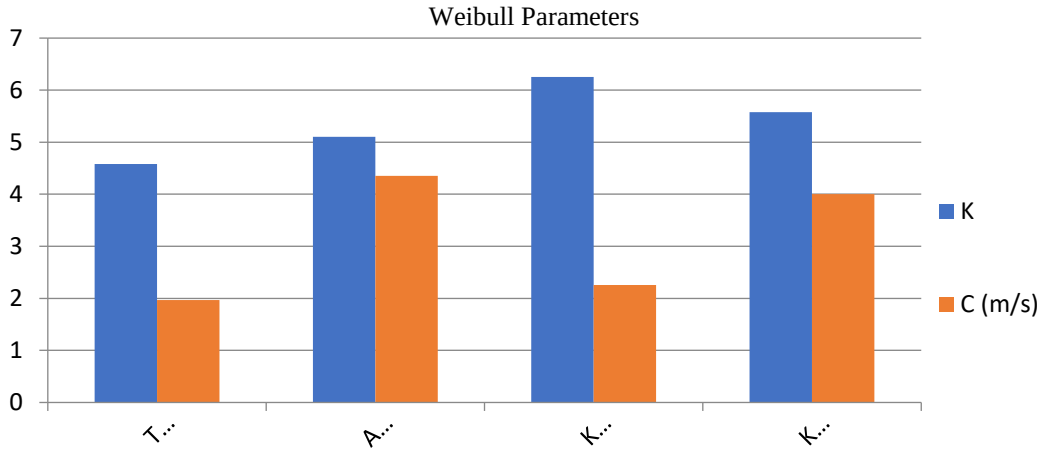

Fig. 6 Weibull parameters for four districts of Kerala

Also, the corresponding value of most probable wind speed are 1.86, 4.16, 2.19, and 3.86 m/s whereas the yearly values of wind speed carrying maximum energy are 2.13, 4.64, 2.36 and 4.23 m/s respectively for the four districts under

investigation. It was further shown that the wind power density of four districts of Kerala are 7.27 W/m^2 for Thiruvananthapuram, 74.89 W/m^2 for Alappuzha, 9.57 W/m^2 for Kozhikode and 55.86 W/m^2 for Kochi respectively. The results obtained of the Weibull statistical analysis for the four districts of Kerala namely Thiruvananthapuram, Alappuzha, Kozhikode, and Kochi are summarized in table 3 to have a better understanding to access the wind energy potential for power generation.

Based on the evaluated magnitude of wind power density [22], a site is considered as very good for wind-to-electricity generation if the value of wind power density is greater than 700 W/m^2, good if it lies between 300 to 700 W/m^2, fairly good if it lies between 100 to 300 W/m^2, and poor if it lies below 100 W/m^2. Wind energy-based power generation uses wind as the only resource, and their output, therefore, depends on the wind energy resource present onsite. A wind resource assessment for a site is the starting point for all wind energy-based power generation projects. Based on the author's investigation, a large fraction of countries does not conduct wind resource assessment sufficiently, and therefore, this results in the inability to harvest the available wind energy resource. Wind resource assessment is the longest and a pivotal step in most wind energy-based generation projects, and it determines the future of a wind energy project [23].

Table 3

Result of Weibull statistical analysis

District	Unit	Thiruvananthapuram	Alappuzha	Kozhikode	Kochi
u_m	ms^{-1}	1.800	4.000	2.100	3.700
σ	ms^{-1}	0.443	0.891	0.388	0.760
u_{max}	ms^{-1}	2.500	5.700	2.700	5.100
K	No Unit	4.582	5.106	6.251	5.575
C	ms^{-1}	1.970	4.351	2.258	4.004
u_{mp}	ms^{-1}	1.867	4.169	2.196	3.865
u_{Emax}	ms^{-1}	2.132	4.642	2.361	4.231
P(u)	Wm^{-2}	7.272	74.892	9.572	55.860

4. Conclusion

After the thorough investigation of results obtained from Weibull statistical analysis, it can be concluded that the four Kerala districts considered in this study namely Thiruvananthapuram, Alappuzha, Kozhikode, and Kochi are not appropriate for large-scale electricity generation from wind power at a height of 10

m above the ground. However, small-scale wind turbines can be installed to extract energy from low-speed wind to convert it into electricity, preferably at a height above 10 m from the ground.

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