Analyzing Wind Speed to generate Electricity by Wind Turbines

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***Abstract* - Wind turbine plays a crucial role in the generation of electricity. Wind turbines have to be constructed at the right place where the entire wind energy can be utilized in an ideal way. Based on the local wind speed, the amount of electricity a wind turbine could generate can be estimated. The objective of this study is to analyze wind power energy which could help to detect whether wind turbines can be set up in a particular location or not. Analyzing wind speed data at different locations helps to predict the wind power generation by wind turbines. The data available over various locations are considered for this analysis. The annual mean is calculated and is stored as mean wind speed and are analyzed to assess the wind power using Rayleigh Distribution method. The Rayleigh distribution is used to represent a probabilistic based model to estimate the wind power in a given region. Using the moving average method, the prediction for the future wind speed is to be done which would further help in the placement of the wind turbines.**

***Keywords* - Wind speed, Wind turbine, Rayleigh distribution, Wind power.**

I. INTRODUCTION

Wind energy is a kind of energy used to make electricity from wind by converting the wind speed into kinetic energy. It is simply like other renewable resources helping the humanity to extract useful energy for day-to-day use. We make use of this data on the wind speed to predict and analyze the future values. Likely wind is created by temperature changes in the troposphere. Thus the warm air rises, cool air moves into the area, and this method of moving creates wind.

The concept of converting wind into electricity is little a tricky process, before that we need to know about the energy. Energy is the ability to do work, or apply a force over a distance. Simply a force is just a push or pull. When the wind blows over an area it is converted into electricity with the help of wind mills. When the wind turns the huge turbines of the wind mill, it produces the valuable kinetic energy, meaning energy due to push or pull. This kinetic energy produced means lot to produce the electricity by rotating the shaft inside the wind mills.

This study on this wind power will definitely help in the installation of wind mills all over the locations of japan, where japan is surrounded by seas which is more favorable for our study. Although there is a debate ongoing whether to move on with wind energy or any other renewable sources, this study may help the management to think about the future plans in investing on the wind resources. Our prediction for the future is based on the current data provided by the government of the country, so there may be no false values and errors occurring. This survey study aims to evaluate the maximum amount of electricity produced at a particular location and compare those values with different locations and help to forecast the future values.

The rest of this paper is organized as: section II deals with wind mills and its principles, background study on distributions is given in section III, section IV deals with related works, the methodology used for obtaining results is discussed in section V and section VI concludes the work of the paper.[2]

II. WINDMILLS

Nowadays we can see windmills in all places where breeze is abundant. In many localities this is the major concept of generating power is windmills. Windmills it is an important invention that can help us to restrict our carbon footprint and save our earth from global warming. In various parts of this earth there is large amount of space and excess of breeze especially in coastal areas, which helps in the installation of wind mills to serve the people with profitable amount of electricity. Many places of India contains windmills, where India uses their wind resources wisely[1].

A. *PRINCIPLE OF WINDMILLS*

The wind power density is the number of watts of electrical energy obtained per square metre of air space (W/m^2).This values are generally given at 10m or 50m above the sea level. The available wind generation capacity is determined by the mean wind speed over the year of location.

For the conversion the wind speed is vital content, here are some characteristics of the wind speed for the turbines:

- 8 kph (2 m/s) minimum is required to start rotating most small wind turbines.
- 12.6 kph (3.5 m/s) is the typical cut-in speed, when a small turbine starts generating power.
- 36–54 kph (10–15 m/s) produces maximum generation power.
- At 90 kph (25 m/s) maximum, the turbine is stopped or braked (cut-out speed).[3]

The working principle is that when the wind passes through the blades, the blades are exposed to bare the lift due to aerodynamic air foil shape. Due to the lift, the blades start rotating. The yaw unit aligns it towards the incoming wind direction when the wind shifts. The rotation of the blades is transmitted through the gear train and couplings to the generator that generates electricity. The generated AC is converted into DC by rectifier for storage in batteries. The electricity is transmitted through the wires to the large storage cells or directly to the transmission.

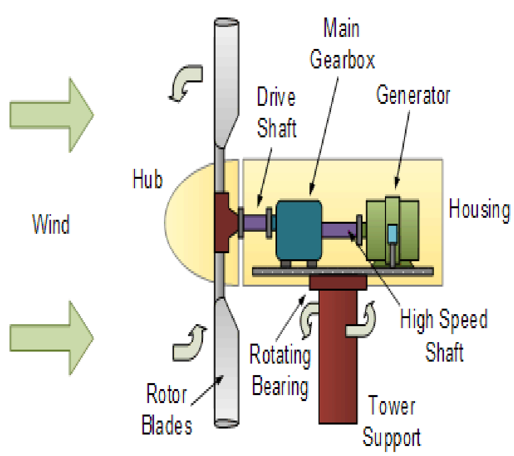


Fig. 1. Wind power generator [2]

A windmill's generation capacity depends on the effective conversion of wind pressure into turbine rotary inertia. Electrical power from the windmill may be available all times of the day, but the output power vary according to the different wind speeds[2].

III. BACKGROUND STUDY ON DISTRIBUTIONS

The previous set of study on "Analysing Wind Speed to generate electricity by Wind Turbines" has been performed by Weibull Distribution with the same type of data. This study is based on the application of Rayleigh Distribution which is a type Weibull Distribution. We hope that the prediction will be more clear by using Rayleigh Distribution. Wind power will be predicted using Moving Average concept.

A. *WEIBULL DISTRIBUTION:*

The Weibull distribution is a continuous probability distribution named after Swedish mathematician Waloddi Weibull. He originally proposed the distribution as a model for material breaking strength, but recognized the potential of the distribution in his 1951 paper A Statistical Distribution Function of Wide Applicability. Today, it's commonly used to assess product reliability**,** analyze life data and model failure times**.** The Weibull can also fit a wide range of data from many other fields, including: biology, economics, engineering sciences, and hydrology (Rinne, 2008). [11]

Standard parameterization:

The probability density function of a Weibull random variable is:

$$f(x;\lambda,k) = \begin{cases} \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-\left(\frac{x}{\lambda}\right)^{k}} & x \geq 0, \\ 0 & x < 0, \end{cases}$$

The Weibull distribution is related to a number of other probability distributions; in particular, it interpolates between the exponential distribution ($k = 1$) and the Rayleigh distribution ($k = 2$ and $\lambda = \sqrt{2}\sigma$)

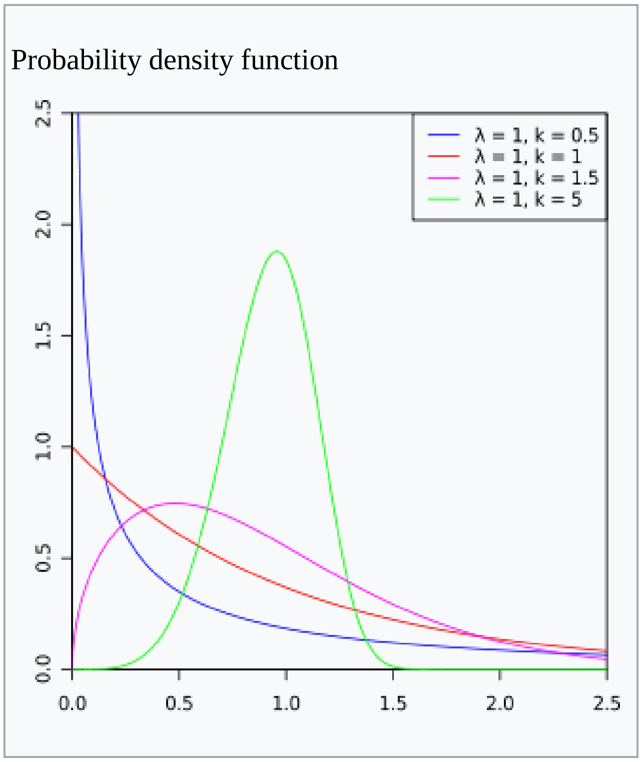


Fig. 2. Probability density function of Weibull distribution [11]

Cumulative distribution function:

The cumulative distribution function for the Weibull distribution is

F(x;k, λ)=1-$e^{-(\frac{x}{\lambda})^k}$

for $x \geq 0$, and $F(x; k; \lambda) = 0$ for $x < 0$.

If $x = \lambda$ then $F(x; k; \lambda) = 1 - e^{-1}$

≈ 0.632 for all values of k. Vice versa: at $F(x; k; \lambda) = 0.632$ the value of $x \approx \lambda$.

The quantile (inverse cumulative distribution) function for the Weibull distribution is

Q(p;k, λ)= $\lambda(-\ln(1-p))^{1/k}$

≈ 0.632 for all values of k.

for $0 \leq p < 1$

The failure rate h (or hazard function) is given by

h(x;k, λ)=$\frac{k}{\lambda}(\frac{x}{\lambda})^{k-1}$

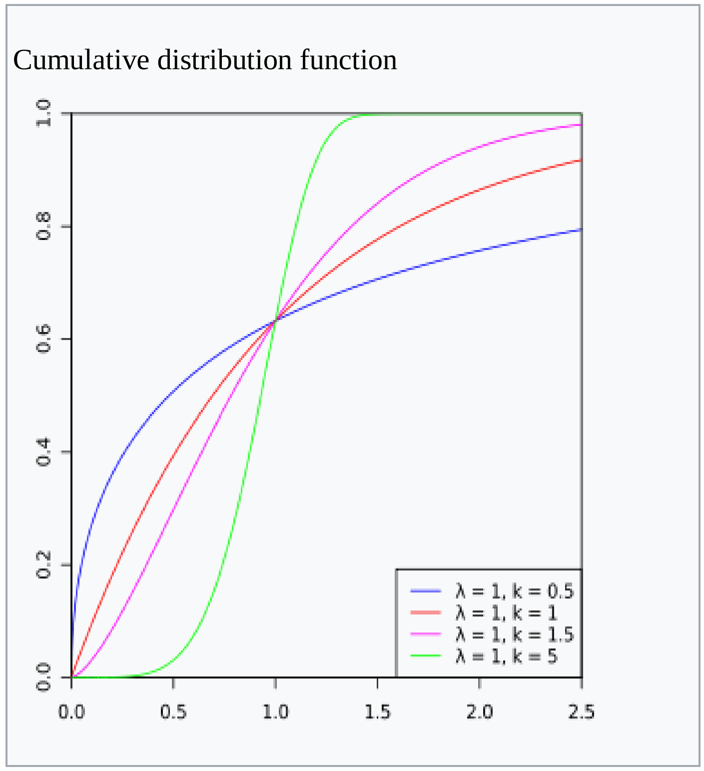


Fig. 3.Cumulative distribution function of Weibull distribution [11]

B. RAYLEIGH DISTRIBUTION:

In probability theory and statistics, the Rayleigh distribution is a continuous probability distribution for positive-valued random variables.[4]

Definition*:*

The probability density function of the Rayleigh distribution is

f(x; σ)=$\frac{x}{\sigma^2}e^{-x^2/(2\sigma^2)}, x \geq 0,$

where σ is the scale parameter of the distribution. The cumulative distribution function is

F(x; σ) $= 1 - e^{-x^2/(2\sigma^2)}$

for x∈ $[0, \infty)$.

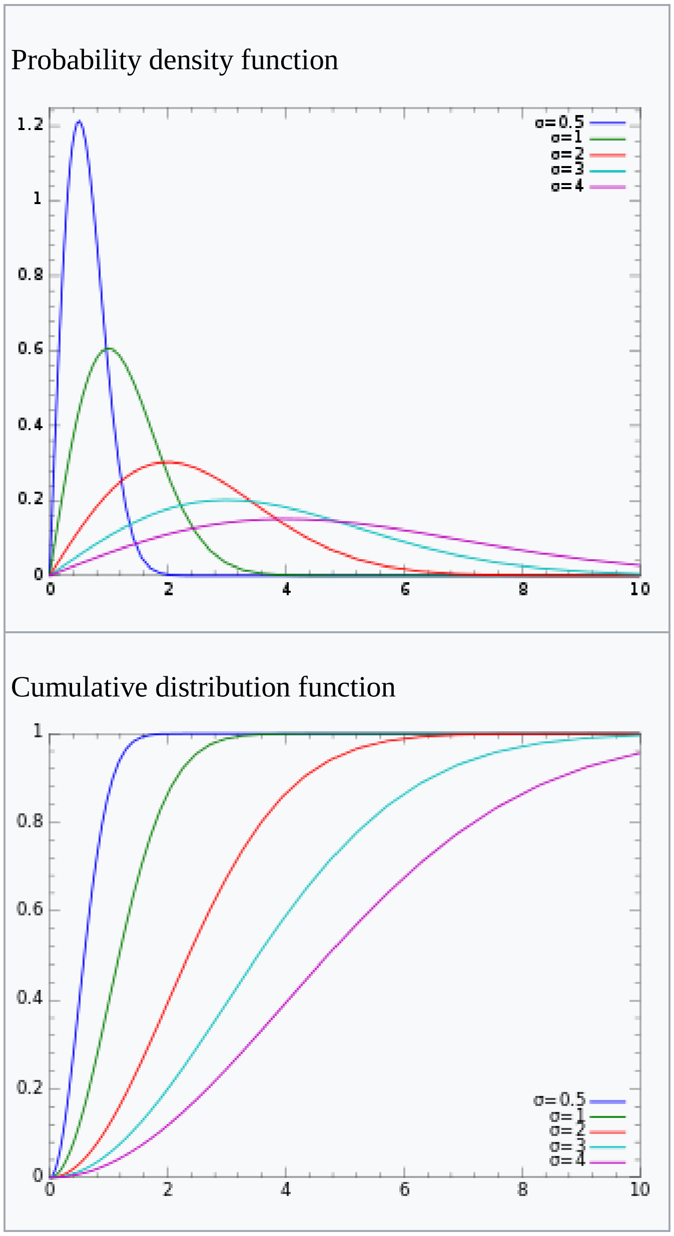


Fig. 4. Probability density and cumulative distribution of Rayleigh distribution. [4]

IV. RELATED WORKS

Ahmad Sedaghat et.al [7] concluded that for some selected wind turbines operating at lower rated wind speeds, the AEP may fall below about 43% of actual achievable AEP when employing higher recommended rated wind speeds. Hence, it is shown that selecting the right rated wind speed wind turbines has great impact on overall energy production of a wind site.

M.H.Souloukngа et.al [8], aimed at analysing the wind speed of Faya-Largeau and making decisions of the cost effective wind turbine for the said zone. In order to determine the wind power density and the available energy for the Faya-Largeau site in the Saharan zone of Chad, the Weibull probability density function was used. Thus, the annual values of the Weibull parameters *k* and *c* are respectively 3.75 and 3.60 (m/s), whereas the power density and available energy are respectively 343.31 W/m^2 and 249.87 kWh/m^2.

The average electrical power, the annual energy produced and the capacity factor are calculated to check the economic viability each wind turbine model. According to Aamer Bilal Asghar et.al [9], wind turbines with rated power 50 kW and 100 kW are most economically viable for available wind resources.

Saïd Zergane et.al [10], presented a new optimization method based on the generation of pseudo-random numbers as a mathematical approach; we have used this method along with the Jensen linear wake model in order to study optimal wind turbine positioning in a farm of given dimensions.

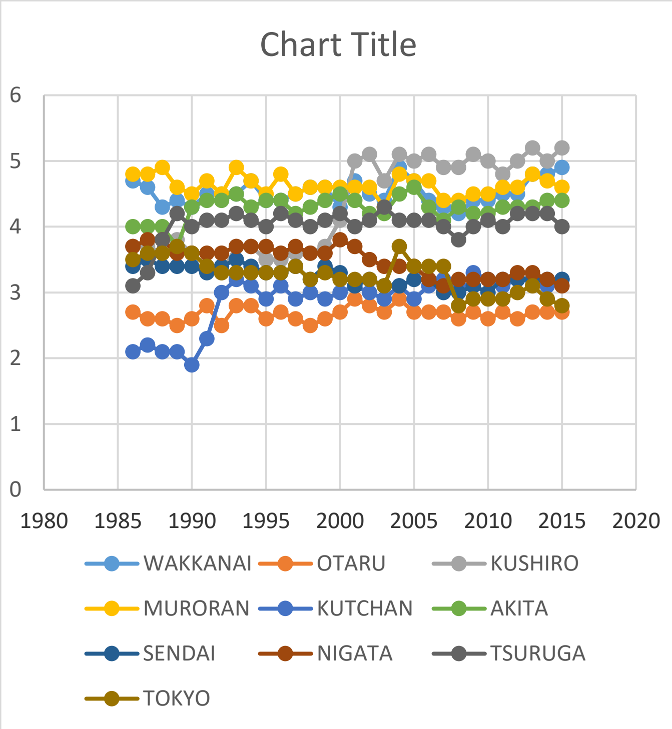
V. METHODOLOGY

The MLE estimates of parameter is given by the formulae and proved as $C=\sum v_i^2/N$ where I is represented as 1,2,3…… n are the mean speeds of the winds. The mean and variance of the wind power P is calculated and found as

$$E(v^3)=\frac{3}{\pi}\, ƒ c^3\left(\frac{\pi}{4}\right)^{3/2}$$

$$Var\,(v^3)=c^6[\gamma(4)-\{\gamma(5/2)^2\}]$$

The value of air density (ƒ) is assumed as 1.225kg/M^3
A program is written to estimate the parameter C and also to estimate the wind power P.
The 10 locations from japan has been selected which would represent the entire country. The mean monthly wind speed data for 30 years has been collected (from 1986- 2015) for the selected 10 locations from japan meteorological agency website (http://ds.data.jma.jp/pbd/stats/data/en/smp/index.html).
The graph of month VS mean wind speed for all the months have been drawn. The wind power potential in each location has been assessed by fitting appropriate Rayleigh distribution and the locations have been ranked in terms of potential wind power availability.



X axis – years Y axis – wind power

Fig. 5. Graph of expected wind power

Moving average method is a device for reducing fluctuations and obtaining trend values with fair degree of accuracy. The moving average is extremely useful for forecasting long-term trends. It can be calculated for any period of time. In this paper, it is used to predict the future wind speed and wind power approximately for 10 years[5].

VI. CONCLUSION

The paper finally indicates the installation of wind power mills in a profitable location, with higher accuracy and true data values. This prediction may result in either positive or negligible negative values of wind power in a particular location.

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