ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 12, Issue 5, September 2023

Resource Assessment and Currents Trends of Wind Energy in India

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Abstract: ***One of the most widely used non-hydro renewable energy sources in the world is wind energy. India is a leading producer of CO2 and one of the nations with the greatest potential for wind energy. At the same time, the amount of wind energy used in states that produce CO2 is remarkably low. In terms of the most significant forces influencing evolution, this study aims to present the current expansion of wind energy. Due to improvements made in wind turbines and foundation structures, which have improved their economic situation and facilitated the installation of offshore plants, there has been a considerable rise in the number of large-scale wind farms in India. Discussion of wind parameters and a preliminary evaluation along with current trends of wind power potential are the main aim of this study.***

Keywords: **Resource assessment, offshore, wind, current status.**

I. INTRODUCTION

Due to growing populations and technological improvements, there is an increasing requirement for energy consumption, which affects the amount of environmental pollution depending on the fuels used to generate the electricity. Climate change is being threatened by coal and oil-based industry because of airborne pollution particles that have significantly increased carbon emissions [1]. The most promising, beneficial, and environmentally benign source of energy is renewable energy. The world can access different renewable energy sources, including wind, solar, biogas, biofuel, geothermal, tidal, and hydropower [2].

The Paris Agreement stipulates that the average global temperature increase shouldn't exceed 1.5 degrees Celsius. Since India has long been a pioneer in renewable energy, especially wind and solar, the government has set a lofty goal of 60 GW of wind power capacity by 2022 [3], with a total renewable energy capacity of 175 GW. At the start of 2021, wind energy accounted for 39 GW of installed capacity, or 10.25 present of the entire power mix. The increased popularity of hybrid tenders that include solar, wind, and storage technologies, as well as the expiration of the inter-state transmission (ISTS) costs waiver in 2023, will drive wind growth over the next five years. Furthermore, the government has set long-term renewable energy targets of 450 GW by 2030, including 140 GW for wind [6].

Additionally, the 7600-kilometer-long coastline of India features relatively shallow oceans. Numerous states in India have enormous wind energy potential [7-8]. It highlights the immense potential for offshore wind generation in Gujarat and Tamil Nadu. The Indian government has announced plans to construct 5 GW and 30 GW of offshore wind farms by 2022 and 2030, respectively, due to the country's high wind potential [9]. There will be 698.043 GW of onshore wind power and 34.367 GW of offshore wind power in 2020 [10].

Rising global average temperatures, shifting precipitation patterns, temperature anomalies, and more frequent occurrences of catastrophic events like hurricanes, floods, and droughts have all contributed to a drastically altered global climate [11]. Significant momentum is being added to the worldwide expansion of renewable energy sources (Fig. 1). Renewable energy (RE) from solar and wind sources is expanding at unprecedented rates. More over 20% of all RE is produced by wind power now, and that percentage is rising [12]. When compared to other top emitters, the rise of renewable energy (RE), especially wind production, is minimal (Table 1).

Overall, the image of WE development in Russia has been organised and examined in accordance with crucial factors that ensure WE implementation success [14]. These components are as follows: local production facilities, organisations that offer training, education, research, and export promotion, permission procedures, investor aid programmes, easily accessible information on wind energy resources.

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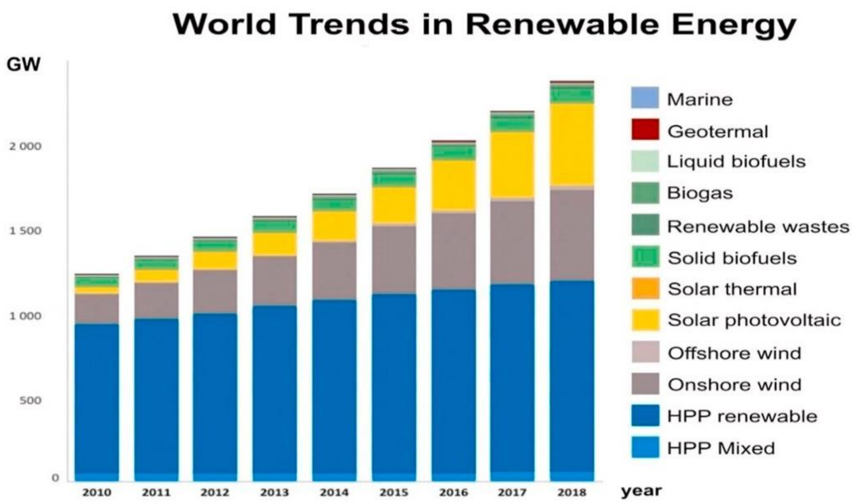

Fig. 1. World trends in renewable energy [12-13].

Table 1. Top 10 countries CO2 emission and wind energy [12, 15].

S.N.	Country	Wind energy installed capacity (GW)			CO_2 emissions per capita (T)	CO_2 emissions (MT)
		2018	2017	2016		
1	China	184.6	164.3	148.5	6.4	9056.8
2	United States	94.2	87.5	81.3	15.0	4833.1
3	India	35.2	32.8	28.7	1.6	2076.8
4	Russian Federation	0.10	0.04	0.011	9.9	1438.6
5	Japan	3.6	3.3	3.2	9.0	1147.1
6	Germany	59.4	55.7	49.5	8.9	731.6
7	South Korea	1.3	1.1	1.067	11.6	589.2
8	Iran IR	0.2	0.19	0.19	7.1	563.4
9	Canada	12.8	12.40	11.9	14.9	540.8
10	Saudi Arabia	0.003	0.003	0.000	16.3	527.2

II. MATERIALS AND METHODS

Correct evaluation of wind resources requires precise wind statistics. In many cases, measurements are taken from a single location, such as an airport or weather station, at a height of 8 or 10 metres [14]. At the utility scale, where wind turbine hub heights can reach up to 100 metres, such data sets are insufficient to assess wind energy projects [14]. Wind generating facilities must have access to data on wind variability and average wind speed at a given time and location [13]. The statistical study of wind and its behaviour requires the use of the probability density function (PDF), the cumulative distribution function (CDF), and other statistical functions [13].
The following equation used to find mean wind speed [13].

$$V_m = \frac{1}{N}\sum_{i=1}^{N} V_i = c\,\Gamma\left(1 + \frac{1}{k}\right) \quad (1)$$

Equation (2) [13] provides the straightforward empirical power law that is utilised to determine wind speed at hub height.

$$\frac{V_2}{V_1} = \left(\frac{H_2}{H_1}\right)^{\alpha} \quad (2)$$

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Weibull distribution

A mathematical model known as the probability density function serves as a visual representation of the random wind speed pattern across time (PDM). According to the research, the Weibull distribution is an indispensable tool for assessing wind energy potential and characterising the frequency distribution of wind speeds in a given location [14].

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (3)$$

$$F(v) = 1 - exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (4)$$

The Weibull parameter estimation method used is Maximum Likelihood Method

$$k = \left(\frac{\sum_{i=1}^{n} v_i^{k} ln v_i}{\sum_{i=1}^{n} v_i^{k}} - \frac{\sum_{i=1}^{n} ln v_i}{n}\right)^{-1}$$

$$c = \left[\frac{1}{n}\sum_{i=1}^{n}(v_i)^{k}\right]^{\frac{1}{k}}$$

Estimation of wind power density

The square of MWS is directly proportional to wind power. The equation [14] used to estimate WPD:

$$\text{WPD} = \frac{\text{P}}{\text{A}} = \frac{1}{2}\rho V_{avg}^{3}\left(\frac{W}{m^2}\right) = \frac{1}{2}\rho c^{3}\Gamma\left(1 + \frac{3}{k}\right)(W/m^2) \quad (5)$$

III. RESULT AND DISCUSSION

MLM method is used to estimate the wind power density (WPD) and compare it to the WPD generated using the wind speed data in Table 2. In Figure 2 we can see how the discovered average wind power density compares to previous estimates. Using Equation (5), we can determine the wind power density. Weibull components are more widely distributed than expected, as shown by the graphical technique.

Data from wind power measurements are more closely reflected in MLM's projections of wind power, according to a statistical analysis. To a lesser extent than maximum likelihood, the power density method approximates the true wind power density. This is due to the fact that data shows even a slight shift in the scale factor (c) value can have a big impact on the wind power density. Therefore, it is expected that better distribution fitting will result from using maximum likelihood to pick the Weibull distribution's parameters.

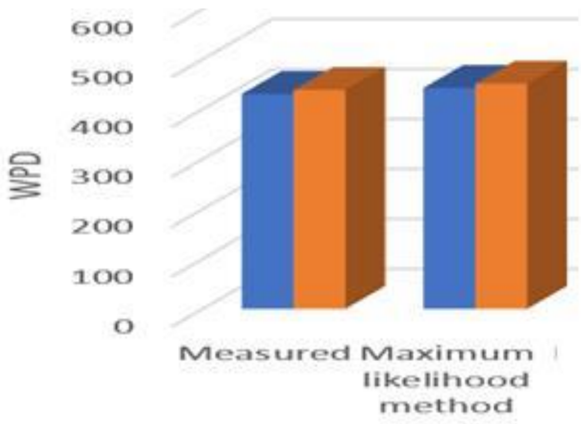

Fig 2: WPD Calculations

Table 2. Measured method

	100 m	120m
Mean WPD	430.35	438.54
Max WPD	3077	3467
Min WPD	2.233	0.049

IV. CONCLUSION

This paper analyses earlier research on wind energy technology and places special emphasis on the potential for utilising both onshore and offshore wind for the production of electricity. Along with the wind resources found on land, more effective wind resources can be found in offshore locations. In the next years, offshore wind energy will be essential to achieving the global goal of renewable energy.

A location's wind power density is a major factor in determining its viability for wind energy development and determining its wind energy potential. Because of their ease of use, flexibility, and precision, the Weibull parameters have been implemented in a number of wind energy research.

We were able to do this by contrasting the Weibull-calculated wind power density with the density found by extrapolating from observed data. The findings show that the values of the Weibull parameters k and c have a significant effect on the values of the wind power density. Therefore, a trustworthy approach is established for determining the parameters c and k for assessing WPD and making effective use of a region's wind resource. The data analysis shows that MLM has a history of success.

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