Assessment of the Wind Power Generation Capacity using A Small Scale VAWT for Central Urban Region of India

Richa Khare[1], Shubham Khare[2], Prashant Sharma[3], Varun Brijpuria[4]
[1] Research Scholar, Energy Technology, SRIST, Jabalpur (M.P.)
[2,3,4] Asst Prof. Department of Mechanical Engg. SRIT, Jabalpur (M.P.)

Abstract- **The aim of the present study is to find out the wind power generation capacity using a VAWT for Jabalpur region located in the Central region of India along with the estimation of performance capability of Gorlov wind turbine performance in the same region.**
The study is concerned with the weather condition of the central Indian region based on the past data collected. The different wind speed with different turbulence intensity is considered and collected from the past weather data. There are five parameters has been considered for the capability and behavior analysis of small scale Gorlov turbine for application in Urban areas are Turbulence Eddy Dissipation (m2/s3).

Index Terms- VAWT, Gorlov Turbine, Wind Power, Turbulence Eddy Dissipation, Turbulence Kinetic Energy, wind turbine etc.

INTRODUCTION

1.1General

Wind turbine innovation offers a financially savvy interchange recharging vitality source. Mention that a wind turbine is fit for producing more prominent measures of electrical vitality with zero nursery impacts contrasted with other vitality creating plans including sunlight-based cell, tsunami, biofuel, hydrogen, biodiesel, and biomass advancements. A wind turbine is the invert of an electrical fan. A wind turbine utilizes wind vitality to create the power; a fan utilizes power to produce wind. In more refined wording, a wind turbine changes over the dynamic vitality of the wind into electrical vitality. Wind turbines come in various sizes and types, contingent upon power creating limit and the rotor configuration sent. Little wind turbines with yield limits underneath 10 kW are utilized basically for living arrangements, media communications dishes, and water system water pumping applications.

1.2 Vertical Axis Wind Turbines History

Vertical Axis Wind Turbines (VAWTs) have customarily been consigned to a specialty class in the general wind turbine advertise. Verifiably their leeway has been that they can create control from wind that originates from any course, as opposed to a Horizontal Axis Wind Turbine (HAWT), which must yaw to represent alters in wind course.

1.3 Evolution of India's wind control industry

This area clarifies the advancement of India's wind control industry, giving careful consideration to the relevant elements: licensed innovation administration, focused power, and natural dynamism. India's wind control showcase has demonstrated a long haul development, with some blast and bust periods because of government arrangement changes. The main blast was activated by the financial change in 1991, which allowed joint endeavors with remote organizations and decreased traditions obligations for imported power hardware from 400% to 25%. Development was additionally determined by different focal government assess motivations (e.g., 100% quickened devaluation on interests in wind control gear, a five-year impose occasion on wind control deals incomes) and state-level approach bolster. Market advancement and different help approaches pulled in private interests in wind control. A few outside organizations entered the Indian wind control advertise through joint endeavors or innovation authorizing.

In any case, since the focal point of these early speculations were mostly on duty motivations (quickened deterioration) as opposed to control age, speculators did not endeavour to adjust imported wind turbines to the neighbourhood conditions, and this brought about problematic execution of wind turbines and doubt in wind control in India. With the end goal to address the quality issues, the primary wind control innovation quality gauges were presented in 1995, and CWET was set up in 1998 with Danish improvement help for the testing and confirmation of wind turbines.

The primary blast time frame finished in FY1996–1997 with an extensive decrease in both focal and state-level tax breaks. For instance, the "base interchange charge" provision required organizations asserting 100% quickened deterioration to pay a 12.9% corporate assessment. The market stagnation was because of the expansion in the Indian Renewable Energy Development Agency's advance loan fees from 4– 5% to 18– 20%. Unexpected approach changes shrank the nation's wind control showcase, and, thus, numerous outside organizations hauled out from the Indian market. The Electricity Act 2003 restored the market, giving a lawful system to advancing sustainable power source. Each state was required to set particular levies and buy sustainable power, guarantee availability of inexhaustible capacity to the framework, and consider the offer of sustainable capacity to any outsider. The market development amid this period prompted a slow increment in focused force, and the quantity of wind turbine makers expanded from 9 in FY2003– 2004 to 19 in FY2014– 2015.

Present vitality framework in India

At present the aggregate introduced control limit of India represents around 233 GW, which is intended to increment to 755 GW by 2030. Besides, the power area of the nation depends essentially on petroleum products, with an aggregate offer of roughly 68%, while the offer of sustainable power source (hydro, sun powered, wind and bio-vitality) and atomic remain at around 30% and 2% separately. The traditional power plants transmit a lot of ozone harming substances. Indeed, the aggregate total CO_2 discharges related with the power division raised from 470 million tons in 2006 to 637 million tons in 2012; i.e. a 6% yearly increment. The discharges of CO_2 and other ozone harming substances created by non-renewable energy source ignition in regular power plants have high effect on natural corruption and in addition on wellbeing state of the populace.

II-LITERATURE REVIEW

K.S.R. Murthy and O.P. Rahi; 2016 introduced a starter Wind Power Potential (WPP) appraisal for beach front site Bheemunipatnam situated in the northern district of Andhra Pradesh, India. The oddity and significant commitment of this paper originates from the way that till date WPP has been done just up to the stature of 80 m and nobody has endeavored it up to the tallness of 150 m in the means of 10 m for said site. Power law has been utilized to gauge WPP at these statures.

Wind control capability of an area must be surveyed for its compelling usage. The target of the examination completed by S.S. Chandel; 2014 was to evaluate the wind asset capability of the western Himalayan Indian province of Himachal Pradesh to distinguish potential destinations alongside giving contributions to strategy producers to misusing wind capability of the area for wind control age and mechanical applications.

A diagram of current status of wind asset appraisal contemplates is exhibited to recognize appropriate methods. Wind Energy Pattern Factor (WEPF) strategy is utilized to evaluate the wind capability of 12 areas covering distinctive landscapes and climatic zones utilizing wind information for the period 2008–2012.Weibull and combined wind appropriations, Weibull parameters and Wind Power Density (WPD) are resolved for these areas. The most elevated day by day mean wind speeds are seen in summers and least in winters in the district. Wind shear examination is done which demonstrates that wind speeds at 30 m, 50 m, 80 m and 100m center point statures are found to increment by 10– 17 % ,26%, 34% and 39% separately than those deliberate at 10m tallness.

III-RESEARCH METHODOLOGY

3.1 General

The significance of decreasing ozone depleting substances prompts creating manageable and productive innovations. Wind control as a free, bounteous, and all-inclusive accessible vitality source is a standout amongst the most encouraging vitality assets for green power age. The normal yearly development in the aggregate introduced wind control limit over the most recent 10 years is over 25% every year; it is foreseen that 12% of the world's power utilization will be given by wind control by 2020. For discovering the wind turbine control age limit in Jabalpur district the accompanying philosophy has been connected.

Figure 3.1 shows the three common main steps in all of these tools: preprocessing, solver, and post-processing. The geometry creation, mesh generation, and boundary conditions definitions are conducted in the preprocessing step. A very important step in solving the partial differential Navier-Stokes (NS) equations is to use and develop stable, consistent, and accurate algebraic replacements for the NS equations, called discretization, where the physics and inherent structure of the problem are retained

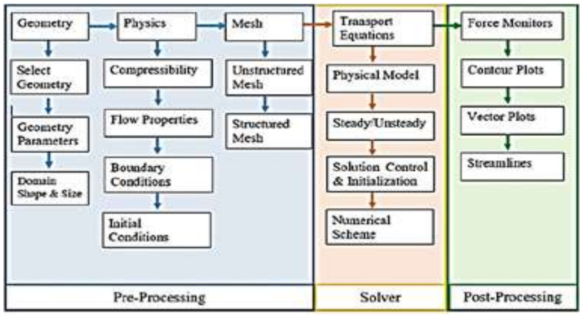

Figure 3.1 Basic Steps in CFD (Weifei Hu; "Advanced Wind Turbine Technology", Springer)

A trade-off between accuracy, computational time, and the objective of the problem determines the most appropriate discretization. The structured and unstructured grid generation can be conducted in a number of mesh tools such as Gambit, Point wise, and ICEM CFD.

Figure 3.2 Gorlov Turbine

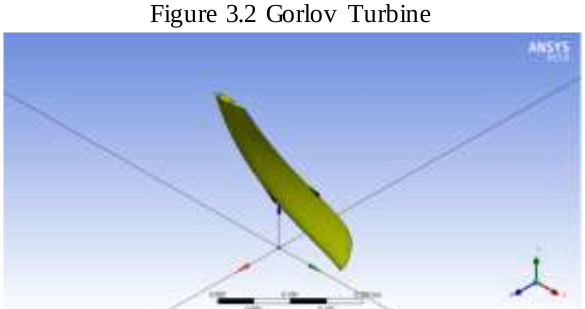

Figure 3.3 Gorlov Wind Turbine Blade

The inner circular domain of the turbine blades is designated as the rotating meshes about the x-axis in a clockwise direction and specifies the rotational speed, ω, as a constant. Stationary meshes are set for the outer rectangular domain. Figure 3.2 shows the Gorlov wind turbine and 3.3 shows the geometry model and 3.4 shows the mesh generated in the wind turbine. The number of nodes and element generated are 33492 and 1904177 Elements have been generated.

Turbulence Model

Inherent turbulent characteristics of the atmospheric airflow make wind turbine rotors' operation impacted by the turbulent fluctuations. There are a number of approaches such as RANS, LES, and detached eddy simulation (DES) for modeling turbulent flows and determining the velocity fluctuations on turbine blades.

IV-RESULT ANALYSIS

4.1 General

A Gorlov wind turbine has been considered for the study using CFD as a tool. There are three different wind velocity i.e. 2,3 and 4m/s has been considered for the study as it is the range of average wind velocity in the last years in Jabalpur region. The turbulence intensity for the analysis is about 1%, 5% and 10% respectively. The following results have been obtained.

4.2 Results for 2 m/s wind velocity and at different turbulence intensity

4.2.1 Results for 2 m/s wind velocity and at 1% turbulence intensity

Figure 4.1 to 4.6 shows the Turbulence Eddy Dissiption (m2/s3), Turbulence Kinetic Energy (m2/s2), Velocity u Gradient, Velocity v Gradient, Velocity w Gradient, Velocity Divergence variation contours for 2 m/s wind velocity and at 1% turbulence intensity.

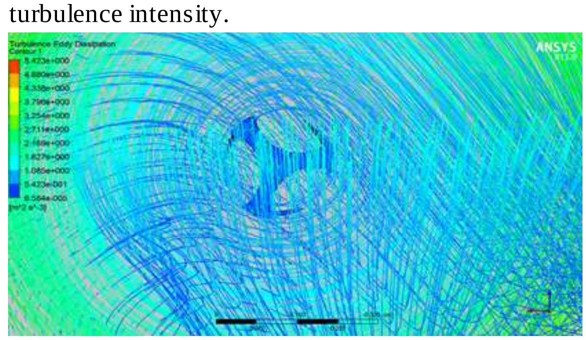

Figure 4.1 Turbulence eddy Dissipation for 2 m/s wind velocity and at 1% turbulence intensity

4.2.2 Results for 2 m/s wind velocity and at 5% turbulence intensity

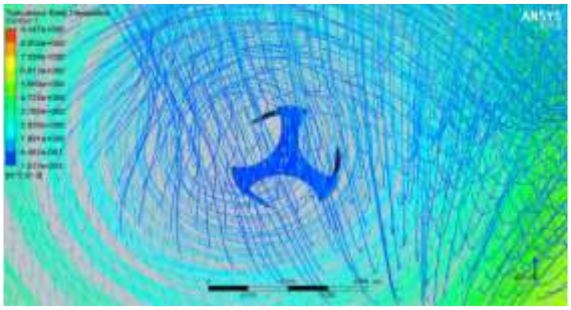

Figure 4.2 Turbulence eddy Dissipation for 2 m/s wind velocity and at 5% turbulence intensity

4.2.3 Results for 2 m/s wind velocity and at 10% turbulence intensity

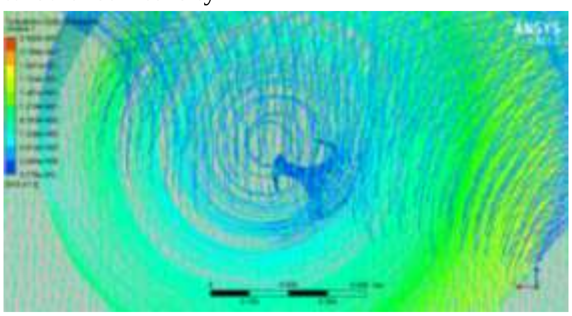

Figure 4.3 Turbulence eddy Dissipation for 2 m/s wind velocity and at 10% turbulence intensity

4.3 Results for 3 m/s wind velocity and at different turbulence intensity

4.3.1 Results for 3 m/s wind velocity and at 1% turbulence intensity

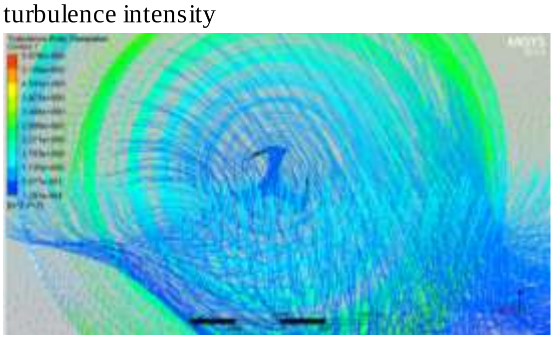

Figure 4.4 Turbulence eddy Dissipation for 3 m/s wind velocity and at 1% turbulence intensity

4.3.2 Results for 3 m/s wind velocity and at 5% turbulence intensity

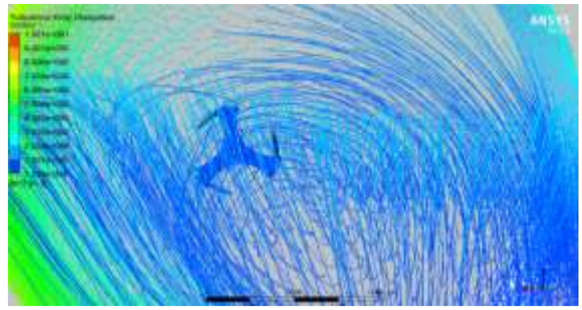

Figure 4.5 Turbulence eddy Dissipation for 3 m/s wind velocity and at 5% turbulence intensity

4.3.3 Results for 3 m/s wind velocity and at 10% turbulence intensity

Figure 4.31 to 4.36 shows the Turbulence Eddy Dissipation (m^2/s^3), Turbulence Kinetic Energy (m^2/s^2), Velocity u Gradient, Velocity v Gradient, Velocity w Gradient, Velocity Divergence variation contours for 3 m/s wind velocity and at 10% turbulence intensity.

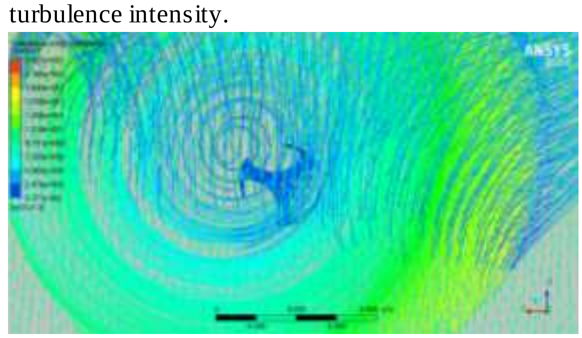

Figure 4.6 Turbulence eddy Dissipation for 3 m/s wind velocity and at 10% turbulence

4.4 Results for 4 m/s wind velocity and at different turbulence intensity

4.4.1 Results for 4 m/s wind velocity and at 1% turbulence intensity

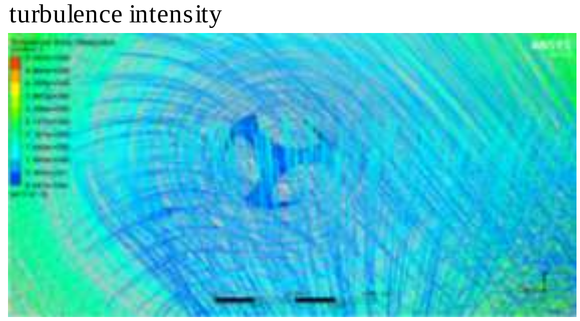

Figure 4.7 Turbulence eddy Dissipation for 4 m/s wind velocity and at 1% turbulence intensity

4.4.2 Results for 4 m/s wind velocity and at 5% turbulence intensity

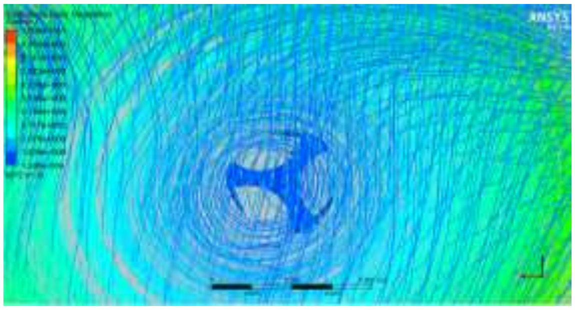

Figure 4.8 Turbulence eddy Dissipation for 4 m/s wind velocity and at 5% turbulence intensity

4.4.3 Results for 4 m/s wind velocity and at 10% turbulence intensity

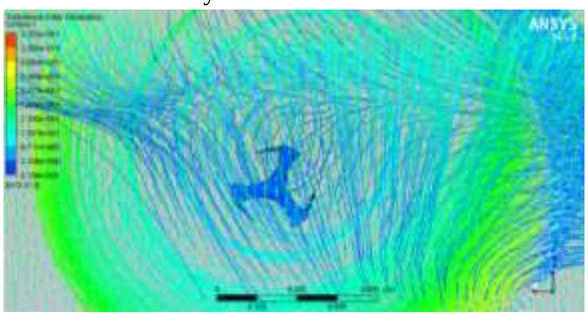

Figure 4.9 Turbulence eddy Dissipation for 4 m/s wind velocity and at 10% turbulence intensity

Discussion

Turbulence is defined as a continuous, three dimensional flow that is nonlinear and contains whirls of different sizes. A fully developed turbulent flow is completely irregular and random and the turbulent eddies effectively transport both energy and matter over time and length scales of varying sizes.

Turbulence Eddy Dissipation

In turbulent flow energy from the mean flow is transferred through the bigger eddies to the fine structures where mechanical energy is dissipated into work (force applied to the turbine blade).

In general, high turbulent flow consist of a spectrum of eddies of different sizes. Mechanical energy is mainly transferred between neighboring eddy structures. For the same reason the main production of turbulence kinetic energy will be created by the interaction between bigger eddies and the mean flow.

The dissipation of kinetic energy into mechanical work, which is due to work done by molecular forces on the turbulence eddies, on the other hand mainly takes place in the smallest eddies. This dissipation curve along with Turbulence intensity and different velocity has been plotted in figure 4.55. It has been found that at high turbulence intensity high eddy dissipation takes place. From 1 to 5% turbulence intensity the eddy dissipation rate is almost same for all the three wind speed considered, while it’s increasing as the turbulence intensity along with wind velocity increases. Thus maximum power can be obtained at high turbulence intensity in case of Gorlov Wind Turbine.

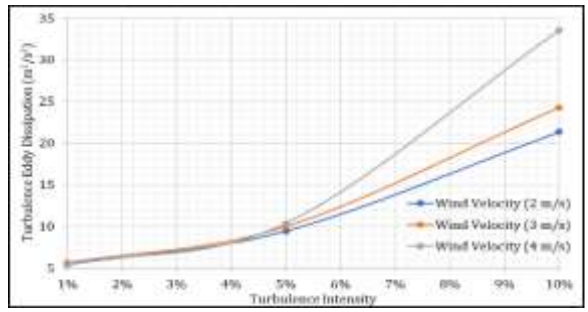

Figure 4.55 Turbulence Eddy Dissipation variation at different wind velocity and Turbulence Intensity

V-CONCLUSION

Micro-scale distributed energy generation close to the end user is one of the trends in the energy sector that is part of the global energy transition. Wind turbines are among the key technologies in low-carbon societies, however, there are challenges which slow its utilization.

In this study, the performance of a Gorlov turbine and its internal flow phenomena were studied by numerical approaches using CFD as a tool and by considering the central Indian weather condition and the estimation has been made for the power production capacity by a small single Gorlov wind turbine for the year. Turbulence Eddy Dissipation (m^2/s^3), is the key variables that has been considered for the study while considering different wind velocity and at different turbulence intensity.

The following conclusion can be made

1. It has been found that at high turbulence intensity high eddy dissipation takes place.
2. From 1 to 5% turbulence intensity the eddy dissipation rate is almost same for all the three wind speed considered, while it’s increasing as the turbulence intensity along with wind velocity increases. Thus maximum power can be obtained

at high turbulence intensity in case of Gorlov Wind Turbine.

REFERENCES

[1] Aki Gronman , Jari Backman, Markus Hansen-Haug, Mikko Laaksonen, Markku Alkki, Pekka Aura; 2018, “Experimental and numerical analysis of vanned wind turbine performance and flow phenomena”, Energy 159 (2018) 827-841

[2] Audrius Jonaitis, Saulius Gudzius, Alfonsas Morkvenas, Mindaugas Azubalis, Inga Konstantinaviciute, Audrius Baranauskas, Vidmantas Ticka; 2018, “Challenges of integrating wind power plants into the electric power system: Lithuanian case”, Renewable and Sustainable Energy Reviews 94 (2018) 468–475

[3] Argüeso D, Businger S, “Wind power characteristics of Oahu”, Hawaii, *Renewable Energy* (2018), doi: 10.1016/j.renene.2018.05.080.

[4] Battisti L, Benini E, Brighenti A, Dell’Anna S, Raciti Castelli M, “Small wind turbine effectiveness in the urban environment”, *Renewable Energy* (2018), doi: 10.1016/ j. renene.2018.05.062.

[5] Bharat Kumar Saxena, K.V.S. Rao; 2015 “Estimation of wind power density at a wind farm site located in Western Rajasthan region of India”, International Conference on Emerging Trends in Engineering, Science and Technology, (ICETEST - 2015)

[6] Daisuke Hayashi, 2018, “Knowledge flow in low-carbon technology transfer: A case of India's wind power industry”, Energy Policy 123 (2018) 104–116

[7] Dimitrios Mentis, Shahid Hussain Siyal, Alexandros Korkovelos, Mark Howells; 2016, “A geospatial assessment of the techno-economic wind power potential in India using geographical restrictions”, Renewable Energy 97 (2016) 77-88