Shrouded Wind Turbines: An Investigation on Maximum Energy Utilization for Kerala Climatic Conditions

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Abstract

Inserting diffuser ducts around a wind turbine is a method to augment its power generation. The output power of a wind turbine can be significantly improved if we can harness the fluid dynamics surrounding a structure to increase the wind speed, specifically if we can catch and concentrate the wind energy locally. When compared to an open turbine with a rotor of an equivalent size, a shroud in a shrouded wind turbine serves to enhance the velocity of the air travelling through the rotor plane. This work aims on investigate the suitability of shrouded wind turbines for Kerala's climatic conditions. For this, wind velocity data collected and analyzed. A basic model is created using ANSYS Workbench and CFD (Computer Fluid Dynamics) analysis carried out on the model created. Results shows that shrouded wind turbines provide an output flow velocity which is more than twice of input airflow velocity and turbulence intensity founded within limits thus helps to obtain high yields even for low wind speeds.

Keywords: *Diffuser, Shrouded wind turbine, CFD (Computer Fluid Dynamics), Duct*

1. INTRODUCTION

An effective duct can help a wind turbine meet the Betz- limit and even go beyond it. In the first instance, it makes sense to utilize this method to increase wind turbine output. If the velocity speed-up ratio is still positive at high upstream wind speeds, the duct's influence will be decreasing at higher wind speeds. Wind turbines for low wind speed circumstances have recently been researched to efficiently convert wind kinetic energy into mechanical energy. There are a significant number of open spaces that could be used for wind energy. Potential areas for wind generation are abundant and accessible.

The majority of Kerala state's energy needs are met by hydroelectric power, which in turn depends on water entering reservoirs but the floods of 2018 and 2019 that impacted Kerala reduces the extent to which we are dependent on reservoirs. In Kerala, there are very few fossil fuel resources, and the vast majority of its hydropower potential has already been used. The emissions from coal- or gas-based power projects in coastal Kerala may have a negative impact on the region's forests, vulnerable marine habitats, and human health. Given these numerous restrictions, Kerala's future energy security is at risk. Since most renewable energy technologies are known to have negligible environmental implications, Kerala's sustainable development and energy security would benefit from a planned transition to renewable energy. Issues with size, noise, flying animals, and other species are the primary topics of contention about wind mills installed. To solve these issues, the design of micro wind turbines has undergone enormous changes in size, form, and noise reduction. Additionally, small-scale wind turbines are becoming more and more popular for generating electricity from the wind all over the world due to the losses associated with electricity transmission and distribution.

The wind energy potential is estimated to be about 605 MW in Kerala by the studies conducted by ANERT. But only 32 MW wind energy generators have been installed in Kerala (Idukki, Palakkad districts) with active private participation. The reasons for this are many, beginning with the geography of the sites to the fact that the State was enjoying the benefits of abundant and cheap hydro power. The hilly terrain of the identified sites is a major hindrance for the development of wind power in the State. Moreover, the sites are located in remote areas, many of which are not connected by proper roads. Most of the available roads are narrow and the curves are too sharp making it impossible to transport the long blades to the respective sites. As a consequence, the capacity of the single units often has to be reduced even though higher potential is available at these sites. Government land is available at many sites but the access to most of the sites is very difficult. Private lands available at the potential sites are mainly agricultural fields and hence land cost is high. As a practice, cranes are used to erect the high wind towers. However, the hilly terrain makes this task difficult and expensive. Additionally due to the remoteness of the locations, power evacuation facilities are also not easily available. This scenario existed shows the importance of ducted turbines which can harvest more energy eliminating these stated drawbacks.

2. METHODOLOGY

The work primarily aims at investigating the possibility and efficiency of shrouded wind turbines for Kerala climatic conditions. For this, first the climate study of Kerala state was done especially wind velocity. From the analysis of this data collected from Indian Meteorological Department and Kerala Disaster Management Department, a basic model of shrouded wind turbine is created and most recorded wind velocity values from the collected data are provided as input flow velocity to find the output velocity of the created model. This is done by Computer Flow Design analysis using the software Ansys Workbench 2021 R2.

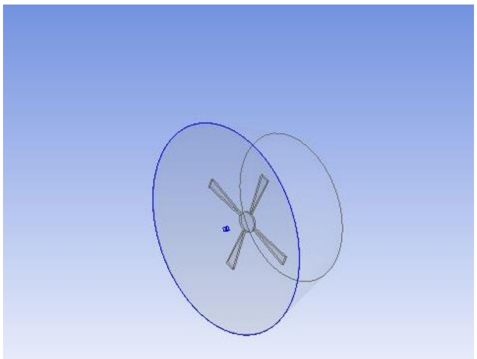

Fig 1- Geometry of Shrouded Wind Turbine

Inlet diameter of duct	1000mm
Outlet diameter of duct	700mm
Length of duct	400mm
Blade length	250mm
Rotor diameter	50mm
Width of blade	10mm
Fan position	Centre

Table 1- Dimensions of created model

3. RESULTS AND DISCUSSIONS

3.1 Inference of Data Analysis

Only in the Palghat Gap region, where winds come primarily from the east from November to March and from the west the rest of the year, are winds over the State seasonal. In other regions of the state, mountain winds and differential heating of land and water masses together control wind flow primarily. Throughout the year, winds have westerly components during the day and easterly components at night. In general, winds are weak at night and very powerful in the afternoons when the thermal circulation is most developed.

The windiest month of Kerala is July and the least windy month is November. In July experience an average maximum wind speed of 6.2 m/s and an average speed 2.7 m/s while in the month of November an average maximum wind speed recorded is 3 m/s and average speed of the month is 0.8 m/s. The maximum wind speed recorded in years 2020- 2022 is 9m/s.

Analysis of wind direction is essential for determining how best to put wind turbines at specific locations, making it a crucial component of any study of the possibilities for using wind energy to generate power. For exhibiting the distribution pattern of the wind direction from a time-series of processed wind speed data, the wind rose technique is typically used. The wind rose diagram displays the frequency of the number of times the wind sustained in a specific direction from 0° to 360° clockwise.

3.2 Results of CFD Analysis

The proposed model which is finalized through CFD analysis was run on Kerala's recorded wind speeds such as 0.1, 0.4, 0.8, 2.7, 4.6 and 6.2 The maximum recorded wind speed, 9m/s, is also analysed to understand the working condition of shrouded wind turbines for low, average and high velocity values of Kerala. This was done to check the suitability of shrouded wind turbines for Kerala's climatic conditions. Results are shown in table 2.

Table 2- Results of CFD analysis

Input air flow (m/s)	**Output velocity (m/s)**	**Turbulent intensity (%)**
0.1	0.246	4.11
0.4	0.969	13.1
0.8	1.94	24.4
2.7	6.595	89.28
4.6	11.2	130
6.2	15.1	169
9	21.9	243

Figure 2 shows the output velocity of created model of shrouded wind turbine for different input airflow velocities.

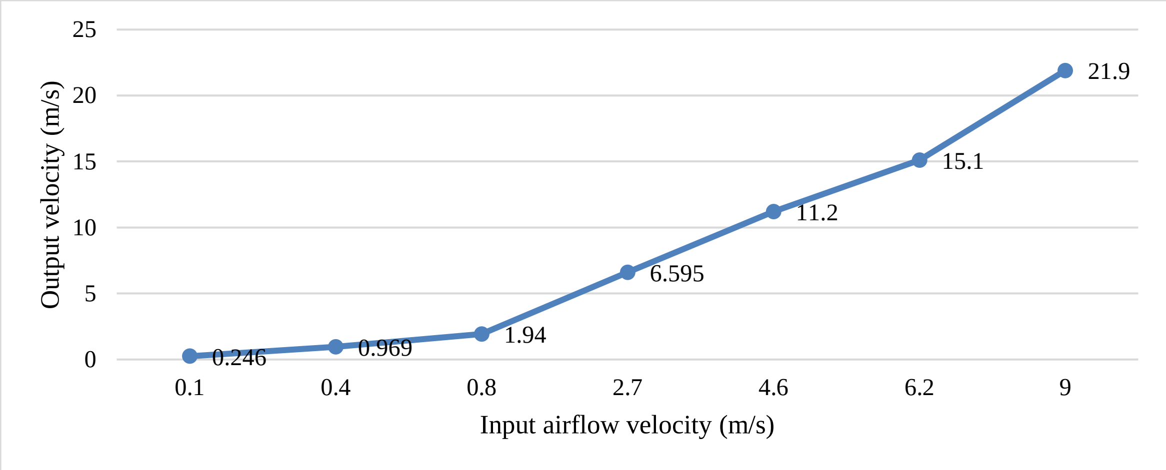

Fig 2- Variation of output velocities for input velocities provided

4. CONCLUSIONS

Kerala is a land with vast wind wealth. A miniature wind turbine with the right dimensions can be used in Kerala for the entire month, according to the results of the finite element study. The created model of shrouded wind turbine provides an output velocity which is more than double of input airflow velocity in CFD analysis. Thus, power of wind is elevated and yields greater energy production. Turbulence intensity values shows that shrouded wind turbines will work in good condition for Kerala climate. Shrouded wind turbines are a better option to harvest the wind energy resources of Kerala.

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