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Research Paper

Use of Continuity of Fluid Flow for Tackling the Location Dependency of Wind Turbines

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Abstract— There is a problem with wind turbines: in order to work, they need sufficient wind velocity, which is why we cannot plan a wind turbine anywhere. That's why we should use the concept of continuity of fluid flow to reduce the location dependency, increase the wind speed, and generate energy anywhere from wind turbines. In the same way that we use wind turbines to generate power, but in this case, we will regulate the wind velocity.

Keywords— Renewable energy **,**Wind energy ,Wind, Wind turbine, Continuity of fluid flow, Ogive cone

1. Introduction

Due to the negative impact of climate change, its unsustainability and other reasons, there is a growing requirement for renewable energy compared to non-renewable (fossil fuels) [1]. Therefore, it is necessary to access new methods to produce renewable energy [2] and modify existing renewable energy sources [3],[4].

There are many examples of renewable energy sources, including solar energy, wind energy, hydropower, geothermal energy, biomass energy, etc., each with their own unique advantages and disadvantages. If we go through it individually with wind energy, it has to show that

Wind energy [5] is a form of renewable energy that uses wind turbines to convert the kinetic energy of the wind into electrical energy. Wind turbines typically consist of large blades attached to a rotor that is mounted on a tall tower. As the wind blows, it causes the blades to rotate, which in turn drives a generator to produce electricity. Despite its advantages, wind energy also has some challenges. While wind energy has many advantages as a renewable energy source, there are also some limitations that need to be considered [6].

Intermittency: Wind energy is an intermittent source of energy, meaning it relies on the wind blowing to generate electricity. When the wind isn't blowing, wind turbines can't generate electricity. This can make it difficult to rely on wind energy as a primary source of energy, as backup sources are needed to ensure a consistent supply of electricity.

Location-dependent: Wind turbines need to be located in areas where there is consistent and strong wind. This can limit where wind farms can be located and make it difficult to generate wind energy in some areas.

Visual and noise impacts: Wind turbines can have a visual impact on landscapes, and some people find them unattractive. They can also generate noise pollution, which can be a concern for people living near wind farms.

Wildlife impacts: Wind turbines can pose a risk to birds and bats, which can collide with the blades. This can have negative impacts on local wildlife populations.

Installation and maintenance costs: Wind turbines can be expensive to install and maintain, which can make them less economically viable in some areas.

Now, for dealing with the intermittent nature of wind flow and the location dependency of the wind turbines, we can use the characteristic of the continuity of fluid flow [7].

Continuity of fluid flow is a fundamental principle of fluid mechanics that states that the rate of mass flow into a control volume must be equal to the rate of mass flow out of the control volume, assuming that there is no accumulation of mass within the control volume.

Mathematically, the continuity equation is expressed as:

$$\rho A v = \text{constant}$$

where,
ρ is the density of the fluid,
A is the cross-sectional area of the flow,
and v is the velocity of the fluid.

This equation means that the mass flow rate (ρAv) is constant along a streamline. In other words, as the fluid flows through a pipe or other conduit, the mass flow rate must be conserved.

The continuity equation is derived from the principle of conservation of mass, which states that mass cannot be created or destroyed, only transferred from one place to another. Therefore, the mass flow rate into a control volume must equal the mass flow rate out of the control volume.

The continuity equation is used extensively in fluid mechanics to analyse the behaviour of fluids in various applications, such as pipes, channels, and other fluid conduits. It is also used to design and optimise fluid systems, such as pumps, turbines, and other fluid handling equipment.

2. Related Work

As per reference [8], wind turbines have been the subject of extensive research and development for several decades. Here are some notable works related to wind turbines:

“Wind Energy Explained: Theory, Design, and Application” by J.F. Manwell, J.G. McGowan, and A.L. Rogers This book provides a comprehensive introduction to the design and operation of wind turbines. It covers a wide range of topics, including wind energy resources, aerodynamics, structural design, control systems, and grid integration.

“Large Wind Turbines” by Siegfried Heier This book provides an in-depth analysis of large wind turbines, including their design, operation, and maintenance. It covers topics such as blade design, gearbox and generator technology, and grid integration.

“Design and Development of High-Efficiency Wind Turbines” by Q. Zhang, Y. Hu, and J. Cao This paper presents a design methodology for high-efficiency wind turbines. It includes a detailed analysis of the aerodynamic performance of the turbine as well as the optimisation of the blade shape and control system.

“Advanced Control Strategies for Wind Turbines: A State-of-the-Art Review” by S. Anwar, M. Ali, and A. Malik This paper provides a review of advanced control strategies for wind turbines, including model-based control, adaptive control, and fault-tolerant control. It also discusses the challenges and opportunities in the field.

“Wind Turbine Blade Design and Performance Comparison of Three Blade Concepts” by P. Bach, M. Zahle, and J. Hattel This paper compares the performance of three different blade concepts for wind turbines. It includes a detailed analysis of the aerodynamic performance, structural design, and manufacturing feasibility of each concept.

“Grid Integration of Wind Energy: Onshore and Offshore Conversion Systems” by Siegfried Heier This book provides an overview of the challenges and opportunities in integrating wind energy into the grid. It covers topics such as grid codes, power electronics, and energy storage systems.

3. Methodology

Firstly, we have to modify the regular wind turbines [9].
A wind turbine typically consists of three main components: the tower, the blades, and the nacelle.
The tower is a tall, cylindrical structure made of steel or concrete that supports the rest of the wind turbine. The height of the tower can vary depending on the turbine’s size and location, but it can range from around 30 metres to over 100 meters.

The blades are attached to a rotor, which is mounted on top of the tower. The blades are usually made of lightweight materials such as fiberglass or carbon fiber, and they are designed to be aerodynamic in order to capture the maximum amount of wind energy. The nacelle is a housing unit located at the top of the tower that contains the generator, gearbox, and other important components of the wind turbine. The nacelle is designed to rotate so that the blades can face into the wind, and it is also equipped with a yaw system that allows it to turn and face the wind from different directions.

Overall, a wind turbine has a distinctive appearance that makes it easy to recognize. The tall tower, large rotor blades, and nacelle are all visible from a distance, and they are often seen in clusters or rows on wind farms.

Now, its large size has to be reduced for domestic and industrial use, and a tangential ogive-shaped cone is needed to be attached to it to increase wind speed and eliminate its dependency upon location and the intermittency of wind.

The design of the wind turbines consists of a two-sided open hollow tangent ogive cone (a “rocket nose cone”) made of acrylonitrile butadiene styrene (ABS) or fiberglass. On the vertex side of the ogive cone, the blades are placed, and the nacelle is connected. A low-altitude, conical-shaped fine net is attached to the periphery of the ogive cone to protect the blades and inner surface of the ogive from solid particles in the air.

Dimensions of the blades and rotor: Curved aerofoil-type blades of 30 cm (0.3 m) length attach to the rotor and provide a 70 cm (0.7 m) rotor diameter to cover approximately 0.384 m2 of swept area.

The dimensions of the ogive cone are:
Depending on the wind velocity where we want to install the turbine, its magnitude is variable.
As a standard, we may go through those measurements.
R=r x $\sqrt{(V_2/V_1)}$ m Eq.—(A.1)
L=2.12xR m or, L=2.12xrx$\sqrt{(V_2/V_1)}$m Eq.—(B.1)
Where ,
R is the radius of the ogive cone.
r is the radius of the rotor.
L is the length of the ogive cone.
V_1 is the wind velocity when it enters the ogive cone.

V_2 is the velocity with which the wind leaves the cone as it passes through the swept area.

Now, in our consideration, the diameter of the rotor is 70 cm (0.7 m).

Then,

$R=0.35x\sqrt{(V_2/V_1)}$ m. Eq.—(A.2)

$L=0.742x\sqrt{(V_2/V_1)}$ m. Eq.—(B.2)

Another measure is

$R'=2.75R$ m. Eq.—(C.1)

where R is the ogive radius.

Dimensions of the nacelle:

The nacelle used here is a mini nacelle of 40cm x 40cm x 40cm , which only consists of the generator.

Conical-shaped net:

The conical-shaped fine net is required to protect the blades and inner surface of the ogive cone. It has the same radius as the ogive cone, and the height of the conical net is one third of the height of the ogive cone. The size of the mesh holes depends on the size of the solid particles where the turbine is installed. Small holes in the mesh reduce the efficiency of the turbine; that's why we have to maximize them or they may detach.

Attachment structure:

The tower, which we easily notice in a regular wind turbine, is neglected; instead, a relatively small structure made of steel is used to connect the ogive cone with the nacelle and provide a base. The base is facilitated as per the location of installation. The turbine may be installed at the uppermost portion of an outer-wall or the roof of a home or industrial building.

This structure is made of a hinge-supported telescopic boom, locking arrangement, and actuator. By regulating the height of the boom, the position of the ogive can be changed towards the direction of the wind flow, and the locking arrangement locks the whole structure in a fixed position. The arrangement of four telescopic booms is set differently depending on where the turbine has to be installed (on an outer wall or on a roof).

The nacelle is attached to the ogive cone by a non-movable arrangement. Below are some figures that may explain the design of the turbine.

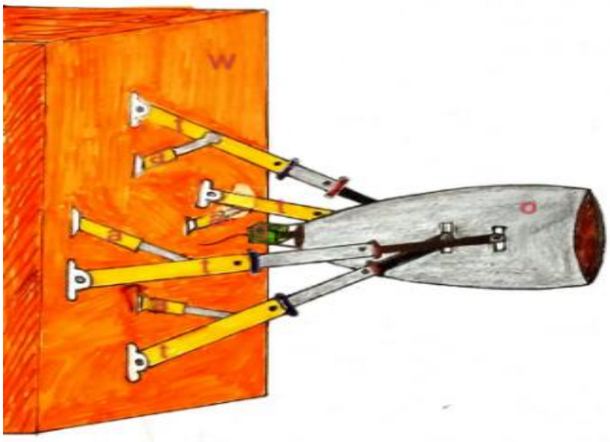

Figure 1. Ogive cone turbine installation in the outer-wall

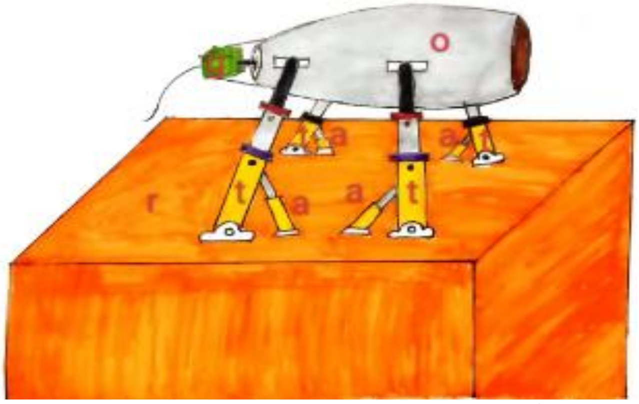

Figure 2. Ogive cone turbine installation on the roof

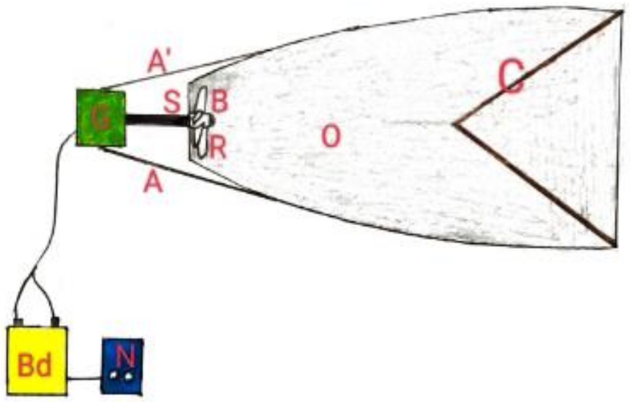

Figure 3. Sectional view of the ogive cone turbine

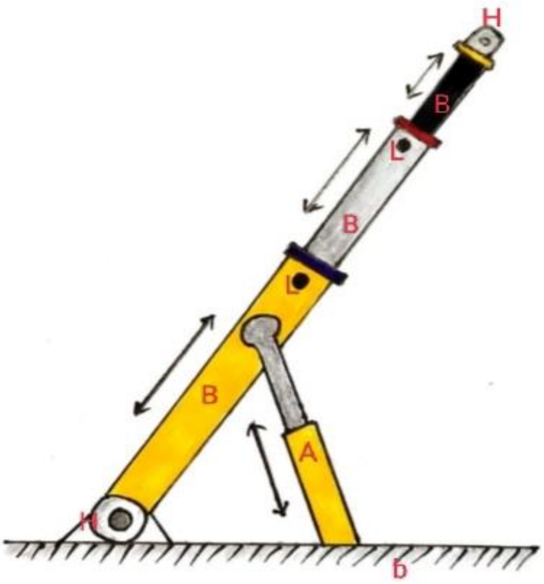

Figure 4. Telescopic Boom

[Note:

Those figures are not to scale; Figure 1 and Figure 2 are the side views of an ogive cone turbine installed in an outer-wall and on a roof, respectively; Figure 3 is the sectional view of the ogive cone; and Figure 4 describes a telescopic boom side view.

Table 1. Index

Figure 1	W: Outer-wall 0: Ogive cone t: telescopic boom a: actuator g: generator
Figure 2	0: Ogive cone t: telescopic boom a: actuator g: generator t: Telescopic boom R: Roof
Figure 3	0: Ogive cone C: Conical net R: Rotor B: Blades S: Rotor Shaft G: Generator A: Attacher N: Invertor
Figure 4	B: Boom L: Frictional lock A: Actuator b: Base H: Hinged Or Pin

The effective length of the ogive cone is always less than 2.12*R (R is the radius of the ogive cone) because the blades are placed perpendicularly upon the central axis of the ogive cone, where the cross-sectional area of the ogive cone is equal to the swept area of the rotor.

The subtracted length (the length difference between the effective length and 2.12*R) is the length of the shaft of the rotor. This gap between the blades and the nacelle provides space for the diffusion of the wind.]

Also for this turbine, the procedure for producing energy is the same as what a regular wind turbine does. The kinetic energy that is stored in the wind is converted into mechanical energy by rotating the rotor blades, and the generator in the nacelle converts this mechanical energy into electrical energy. This produced energy is stored in a battery bank or may be further distributed.

4. Discussion

The energy produced by a wind turbine can be determined mathematically using the following formula:

Energy produced = $0.5 \times A \times \eta \times \rho \times V^3 \times t$ Eq.—(D.1)

Where: A = the swept area of the turbine blades (m2)
H = the power coefficient of the turbine (dimensionless, typically between 0.35 and 0.45)
P = the density of air (kg/m3, typically around 1.225 kg/m3 at sea level.
V = the wind speed (m/s)
T = the time the turbines operate (in hours).

To use this formula, you will need to know the values of A, η, ρ, V and t. These values can be estimated or measured, depending on the situation.

For example, if a wind turbine has a swept area of 100 m2, a power coefficient of 0.4, the density of air is 1.225kg/m3, the wind speed is 10 m/s, and it operates for 24 hours, the energy produced can be calculated as follows:

Energy produced = $0.5 \times 100 \times 0.4 \times 1.225 \times 10^3 \times 24 = 588$ kWh

This means that the wind turbine would produce 588 kilowatt-hours of energy over a 24-hour period.

588 kWh is a relatively large amount of energy that is not possible to gain using this ogive cone turbine within the given time period because of its small size and low swept area, which processes a low quantity of wind. But despite this disadvantage, the ogive cone turbine is capable of producing wind energy anywhere using wind of any velocity in an economical manner with other advantages that a renewable energy source has.

And, it is obvious that for producing 588 kWh of energy, the first requirement is a wind velocity of 10 m/s, which is location-dependent; wind velocities vary as per location. Now, if we use an ogive cone turbine in places with low wind velocity, its area difference between the two ends can supply sufficient velocity as per the principle of continuity of fluid flow.

For an ideal case, we assume that the velocity of the wind in a place is 1 m/s.

Let’s, as per this assumption, modify the wind turbine to get some amount of energy.

Firstly, we use a 0.7 m (70 cm) diameter rotor to cover approximately 0.384 m2 of swept area.

Now, the radius of the ogive cone is $R = 0.35 \times \sqrt{(V_2/V_1)}$ m. As per Eq. (A.2)

Where V_2 is the wind velocity that leaves the cone through the swept area of the ogive cone, and it has to be 10 m/s for better efficiency.

And V_1 is the entering wind velocity of 1 m/s as per the assumption.

:. $R=0.35 \times \sqrt{(10/1)}=1.107$m

Length of the ogive cone, L = 2.12R (as per Eq.—(B.1))
:. L= 2.35 m
This length L is the total length, the length of the gear shaft, and the effective length of the ogive cone.

The blades are placed perpendicularly upon the central axis, where the cross-sectional area of the ogive cone is equal to the swept area.

Using this dimension of the modified ogive cone turbine, we obtain a sufficient velocity of 10 m per second, whose kinetic energy converts to electrical energy.

Now, determining the wind energy, E, by putting the value of the parameters, we get:

$$E = 0.5 \times A \times \eta \times \rho \times V^3 \times t. \quad \text{(As per Eq.—(D.1))}$$
$$= 0.5 \times 0.384 \times 0.4 \times 1.225 \times 10^3 \times 24$$
$$= 2262.889 \text{ Wh}$$
$$= 2.26 \text{ kWh}$$

This means that the wind turbine would produce 2.26 kilowatt-hours of energy over a 24-hour period.
Similarly, as per requirement, we can modify the dimension of the ogive cone turbine to produce the demanded wind energy.

5. Conclusion and Future Scope

To tackle the challenges of a wind turbine, such as intermittency of wind and location dependency, it is proposed to modify the turbine with an ogive cone, which solves the above problems as per the principle of continuity of fluid flow. This arrangement is not capable of producing the same amount of energy as a regular wind turbine, but it can easily produce a holistic amount of energy as per demand.
This type of modification is required for a sustainable, global-warming-free future. This ogive cone turbine is more economical and environmentally friendly than other renewable energy sources while producing the same amount of energy.

Data Availability

None.

Conflict of Interest

I do not have any conflict of interest.

Funding Source

None.

Authors’ Contributions

All the research work was done by me (SK Asraful Karim) ,I researched the literature, conceptualized the study, designed it, drafted the manuscript, and did other necessary things.

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Author: Sk Asraful Karim, a 3rd year mining engineering student in the Department of School of Mines and Metallurgy at Kazi Nazrul University, Asansol, West Bengal, India.

As a student, I have an interest in venturing into studies related to engineering and innovation, sustainable development, and renewable energy because of my curiosity about the phenomenon of the multiverse, its workings, principles, and causality.


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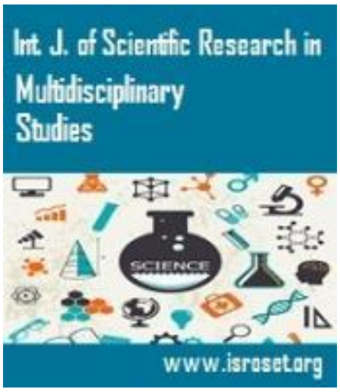
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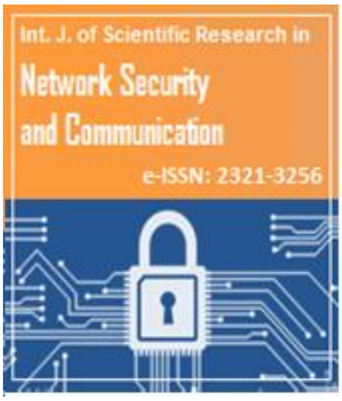
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