

Vortex Bladeless Wind Energy Conversion System: Stator Coil Design and Simulating Wind Flow

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ABSTRACT: Vortex Bladeless is a vortex induced vibration resonant wind generator. It harnesses wind energy from a phenomenon of vorticity called Vortex Shedding. Basically, bladeless technology consists of a cylinder fixed vertically with an elastic rod. The cylinder oscillates on a wind range, which then generates electricity through an alternator system. In other words, it is a wind turbine which is not actually a turbine.

Vortex wind generators are more similar in features and cost-effectiveness over time to solar panels than to regular wind turbine

Our bladeless wind turbine captures the energy from the wind by a resonance phenomenon produced by an aerodynamic effect called vortex shedding. In fluid mechanics, as the wind passes through a blunt body, the flow is modified and generates a cyclical pattern of vortices. Once the frequency of these forces is close enough to body's structural frequency, the body starts to oscillate and enters into resonance with the wind. This is also known as Vortex Induced Vibration (VIV).

KEYWORDS: B – magnetic field strength, B_r – residual induction of magnet, D – outside diameter of the ring, d – inside diameter of the ring, f- frequency, L – thickness, l- length of the mast, P – number of poles, ϕ - magnetic flux, N – number of turns, α - proportional symbol, ρ - density, π - pi (3.14), v- velocity, V – voltage induced, VIV- vortex induced vibration, x- air gap

I. INTRODUCTION

Wind energy has become an essential part of the global renewable energy landscape and dependence on it is anticipated to increase in the foreseeable future. At present, wind turbines are the most commonly used machines for converting wind energy into electrical energy, with the movement of the blades fuelling an electricity generator. The wind turbines in use at present have blades that rotate due to the force exerted by wind and convert the rotational mechanical energy into electricity. Wind turbines with blades have their own advantages and disadvantages. Instead of deliberating on the advantages, it is more important to highlight the disadvantages associated with the use of blade technology. The issues associated with bladed wind turbines include transportation problems, the need for a strong foundation, mechanical wear and tear, lower rotational efficiency and noise pollution caused by the rotation. These problems are compelling innovators and engineers to look at bladeless wind turbines. Vortex bladeless turbine antiquates the conventional wind turbine and adopts a radically innovative and novel approach to captivate the moving wind energy. This device effectively captures the energy of vorticity, an aerodynamic instability condition. As the wind passes a structure, the flow steers and cyclical patterns of vortices are generated.

Once the strength of wind force is suffice, the structure starts vibrating and reaches resonance. Vortex bladeless is a vortex induced vibration resonant power generator. It harnesses wind energy from a phenomenon of vorticity, called vortex shedding effect. Clearly bladeless technology consists of a cylinder fixed vertically on an elastic rod, instead of tower, nacelle and blades which are the crucial parts of a conventional wind turbine. The cylinder oscillates on a specifically mentioned wind range, which then generate electricity through an alternator and a tuning system.

The energy extraction method from wind using vortex induced vibration (VIV) of a cylindrical body (called as mast) in wind is a novel method and can be a renewable and nonpolluting power source.



This mode of energy conversion with bladeless technology doesn't require land spaces like normal wind turbine power plants and will not affect bird's life. Also, when compared to conventional wind turbine, the materials required for this technology is significantly less.

This technology can be implemented in any place unlike conventional methods.

1.2 Frequency tuning

The frequency of the Vortex shedding is proportional to the windstream's velocity, however each structure has its own natural vibration frequency. To match wind frequencies with a device's natural frequency you should modify the body mass (the more mass the less natural frequency) and the rigidity (the more rigidity, higher frequencies), among other parameters. Therefore, you would need complex mechanisms to vary the natural frequency of that device.

To avoid this, Vortex design uses instead a magnetic confinement system with permanent magnets that increase the apparent stiffness of the system according to their degree of flexion. The degree of flexion grows as long the wind intensifies. We call this "tuning system".

II. RELATED WORK

WORKING-

The vibration of upper part of the body (mast) in wind results in, reciprocating motion of a magnet (fixed inside the mast) around a stationary coil and thus generating power.

In order to maximize the power, the vibration of mast needed to be tuned to its natural frequency to have a resonating effect (enhancing the vibration) according to the variation in wind speed.

If we can tune the natural frequency of the mast according to the wind velocity by using a tuning mechanism, the mast vibrate at its resonance, which enhances the vibration and hence the power output

How to determine the number of turns required on the stator coil and calculate the output put voltage based on magnetic force.

When the coil current increases so does the magnetic field strength, H . That, in turn, leads to an increase in magnetic flux, Φ . The increase in flux induces a voltage in the coil. It's the power needed to push the current into the coil against this voltage which we now calculate.

The Biot Savart Law is used to determine the magnetic field intensity B near a current-carrying conductor or we can say, it gives the relation between magnetic field intensity generated by its source current element. The law was stated in the year 1820 by Jean Baptiste Biot and Felix Savart.

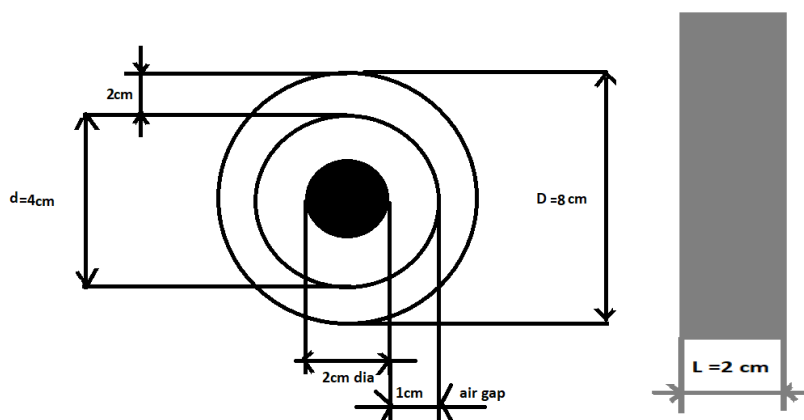


Figure 1



NUMERICAL CALCULATIONS-PERMANENT MAGNET – FERRITE MATERIAL DIMENSIONS USED –
 Outer dia (D)=8cm, Inner dia(d) = 4cm Thickness(L) =2cm COIL USED – COPPER used is 1mm dia. STATOR ROD – IRON ROD 2cm dia.

(1mm diameter used for coil is standard)

SOLUTION –

PART -A The voltage induced is directly proportional to number of coils and also field magnetic-strength

V proportional to N, P, B

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Where- N = No. of turns

V = Voltage induced

P = No. of poles

B = magnetic field strength

$$V = f \times N \times P \times B \quad -1)$$

Where- f= Frequency of the mast

- By dimensions of the permanent magnet

Therefore, the frequency of the mast is given by

$$f = (2 \times 10^{-2} \text{ m}) / \text{time taken}, \quad \alpha \text{ wind speed}$$

So this frequency is directly proportional to wind speed

hence,

$$f \propto \text{wind speed.}$$

MAGNETIC FIELD STRENGTH (B)- PART-B

Since the magnet used is a permanent magnet instead of electromagnet, Ampere law cannot be used.

The Biot Savart Law is used to determine the magnetic field intensity B near a current-carrying conductor.

Therefore, we use BIOT- SAVARTS law

According to BIOT SAVART LAW, field strength is,

$$B(x) = \frac{Br}{2} \left\{ \left(\frac{L+x}{\sqrt{r^2+(L+x)^2}} - \frac{L}{\sqrt{R^2+(L+x)^2}} \right) - \left(\frac{x}{\sqrt{R^2+x^2}} - \frac{x}{\sqrt{r^2+x^2}} \right) \right\}$$

Where Br- Residual induction of magnet x – air gap

Br of ferrite magnet is 3500 Gauss

$$B(x) = \frac{3500}{2} \left\{ \left(\frac{2+1}{\sqrt{\left(\frac{4}{2}\right)^2+(2+1)^2}} - \frac{2+1}{\sqrt{\left(\frac{8}{2}\right)^2+(2+1)^2}} \right) - \left(\frac{1}{\sqrt{\left(\frac{8}{2}\right)^2+(1)^2}} - \frac{1}{\sqrt{\left(\frac{4}{2}\right)^2+(1)^2}} \right) \right\}$$

$$= 1750 \times 0.4363$$

$$= 764.27 \text{ Gauss} = 764.23 \times 10^{-4} \text{ Tesla}$$



For a led light to glow we need at least 4 Volts

From equation 1)

$$N = V / (f \times P \times B)$$

Since frequency is directly proportional to wind speed,

suppose **f= 4 Hz** **P = 2 poles**

$$N = 4 / (4 \times 2 \times 764.27 \times 10^{-4})$$

$$N = 6.56 \quad = \underline{7 \text{ turns}}$$

Voltage V = 4 volts.

WIND POWER- PART-C

Wind speed = 11m/s

Length of the mast (l) = 50cm = 0.5 m

Air density (ρ) = 1.23Kg/m³

Area = (π) X l² = .785 m²

Power = (1/2) X (ρ) A X V³ = (1/2) X 1.23 X .785 X 11²

= **58.41 watts**

III. SIMULATION RESULTS

Advantages of bladeless turbines

- There is no need for nacelles, support mechanisms and blades – costly components used in conventional wind generators.
- Bladeless turbines are very lightweight and have their gravity centres close to the ground. Thus, anchoring or foundation requirements are reduced significantly compared to regular turbines, easing installation.
- The lower cost of manufacturing and maintenance of these turbines may contribute to an increase in their demand.
- These turbines do not suffer large drops in power as their smaller swept area allows more turbines to be installed within the same surface area, compensating for the loss of power efficiency with space efficiency, in a cost-effective way.
- Bladeless wind turbines contain few moving parts, which helps in eliminating the noise generated by bladed wind turbines.
- Vortex turbines aim to be greener and noiseless alternatives in the wind power segment, as their simple design and light weight allow very efficient use of raw materials.
- Vortex Bladeless turbines are mainly a solution for distributed energy generation and are perfect for installation near houses or on roofs.
- Bladeless turbines can work on-grid and off-grid, and can also be part of hybrid wind-solar installations.
- Vortex’s design allows the oscillatory movement in bladeless turbines to be tiny and thus less aggressive than traditional wind turbines. As a result, they do not disturb wildlife and allow birds and bats to avoid them easily while flying.

3.4 Material used in our project-

Fan



Figure2

Anemometer



Figure 3

An **anemometer** is an instrument that measures wind speed and wind pressure. **Anemometers** are important tools for meteorologists, who study weather patterns.

Ring magnet

In this a permanent magnet we use is a ring magnet having ferrite materials in order to have magnetic properties.

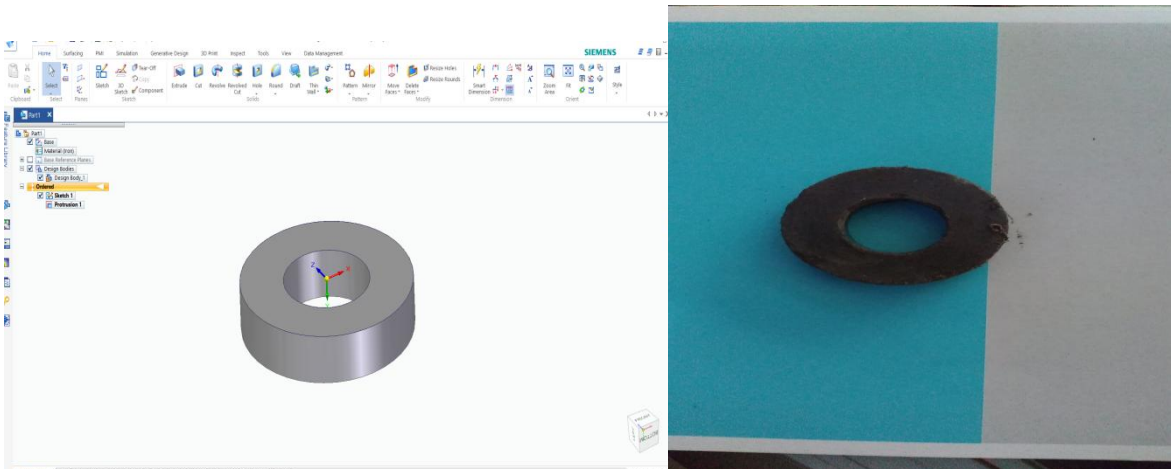


Figure 4 (a) and (b)

Copper coil



Figure 5

Iron rod



Figure 6

The copper coil is wound around the iron rod. The iron rod is kept stationary, so when the ring magnet fixed in the mast oscillates, magnetic flux is cut due to which voltage gets induced in the coil.

WHY CANNOT WE USE HOLLOW CORE-

Due to the presence of eddy current formation in the hollow core we use solid iron rod shaft. Also in hollow core, due to the presence of air gap in between, the voltage fluctuations will take place.

IV. CONCLUSION

In this work we intend to give a wind speed from the fan of about 0-11m/s.

The fan has a regulator in order to vary the wind speed according to the requirement of vortex shedding.

In this study we were able to determine that for N number of turns in a stator coil for 7 numbers, we get output voltage as 4 volts based on magnetic strength which is determined with the help of Biot Savarts law.

The frequency that we considered for this study is 4hz, because frequency is directly proportional to wind speed.

The power determined in this study is 58.41 watts. For this purpose, we considered the length of the mast as 50cm and wind speed as 11m/s.

In this study we are able to determine that,

- 1) Number of turns in a stator coil = 7 turns
- 2) Voltage induced based on magnetic force = 4 volts
- 3) Power generated = 58.41 watts

NOTE- The values determined are purely theoretical.

Wind turbine technology has demonstrated the potential for contributing to the energy needs of the United States. If the sites with acceptable wind characteristics were fully utilized, they could contribute up to about 10 percent of the nation's electrical energy needs.

So if we utilize this form of renewable energy then more power can be produced from less space required.

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