

Harnessing Savonius Wind Turbines for Sustainable Energy Production in Rural Regions

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ABSTRACT

The main objective of this project is to design and develop a vertical axis wind turbine suitable for power generation in rural areas. Vertical Axis Wind Turbines (VAWTs) are selected because they utilize drag force to capture wind energy, offer high starting torque, and function efficiently regardless of wind direction. In this work, a prototype of a Savonius-type VAWT is fabricated using easily available materials such as plywood, sheet metal, and bearings, making it cost-effective and practical for rural applications. The system is specifically designed to be mounted on rooftops, allowing better utilization of available space.

Environmental challenges have always been a major concern in engineering, and renewable energy solutions like wind turbines play an important role in addressing these issues. This project focuses on creating a sustainable energy solution that not only supports environmental conservation but also promotes self-reliance in rural communities. By encouraging a gradual shift away from fossil fuels, this initiative contributes to reducing carbon emissions and expanding the use of clean energy technologies.

KEYWORDS: *Wind turbines, “s” shaped blade, Vertical Axis Wind Turbine, (VAWT), Savonius rotor, Low-velocity turbine, Wind energy, Electrical energy*

INTRODUCTION

Renewable energy is an environmentally favourable energy source since it emits no carbon dioxide. According to the International Energy Agency, only a small portion of energy comes from hydropower and nuclear power, with a much smaller portion coming from renewable energy sources such as wind energy, solar energy, biomass, geothermal energy, and tidal waves. Wind energy is an environmentally benign energy source that also helps to mitigate environmental changes caused by greenhouse gases released by the combustion of fossil fuels. According to the review, there are around 10 million MW of energy available on the planets as wind energy. A wind turbine is a one-of-a-kind device that converts wind energy to electrical energy.

WIND

Because of the sun's beams, the Earth's surface heats, as does the atmosphere. When direct sunlight touches the Earth's surface, warm air is generated. Other locations have cold air. Cold air is heavier than warm air. Warm air rises due to its lighter weight. The idea is for cool air to flow in and replace the rising heated air. The creation of air is what causes the wind to blow.

Wind Turbine Classification

Horizontal and vertical axis wind turbines are the two basic types of wind turbines (HAWT and VAWT). The most popular wind turbines feature horizontal axis blades that revolve on an axis parallel to the ground.

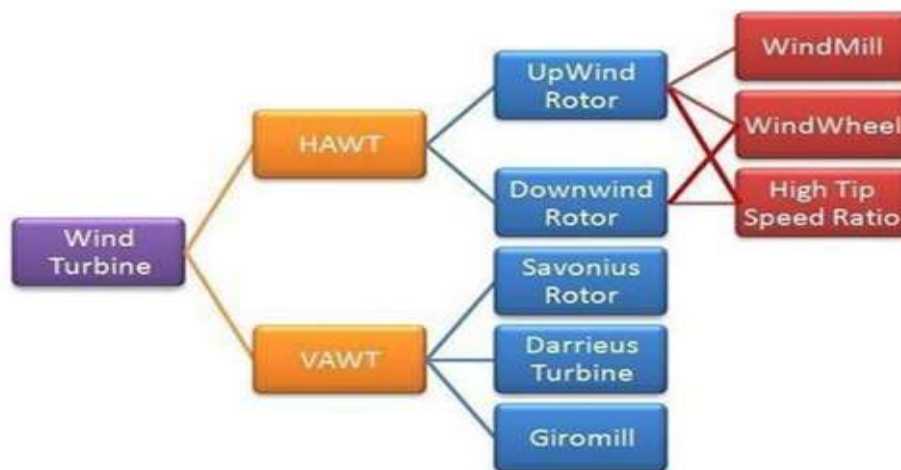


Figure 1: Wind Turbine Classification.

Horizontal Axis Wind Turbines (HAWT)

Wind turbines with a horizontal axis generally have two or three blades. These wind turbines are used when they are "upwind," with the edges pointing into the breeze. All commercial wind turbines on the market are horizontal axis devices with rotors that use two or three airfoil edges. The rotor cutting edges are attached to a hub and coupled to the main shaft, which routinely rotates a generator with transmission via a gearbox.

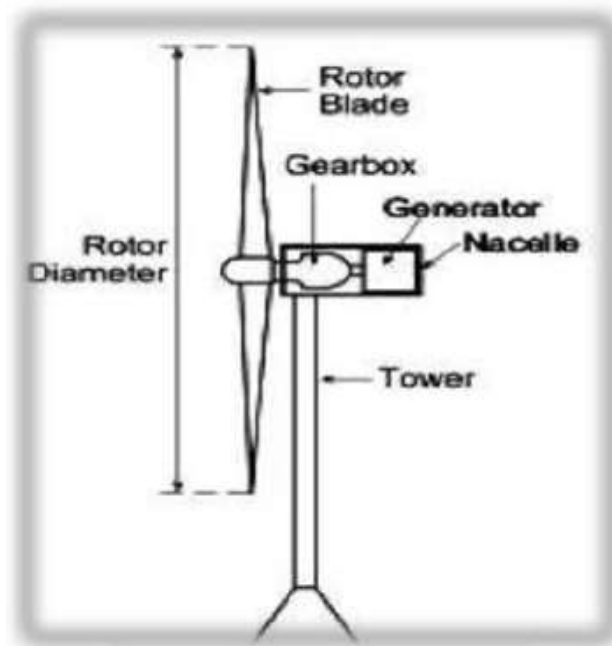


Figure 2: Horizontal Axis Wind Turbines

Vertical Axis Wind Turbines (VAWTs)

The primary rotor shaft of a vertical-axis wind turbine (VAWT) is mounted vertically. Wind direction changes have no effect on this type of turbine since it should not be located in the wind direction. According to the guideline utilized to collect the wind flow, VAWT is categorized as Darrieus and Savonius turbines. Savonius turbines are the most basic type of turbine. They are drag-type devices that consist of two or three scoops that approximate an "S" shape in a cross-section. Because of the curvature, it experiences less drag while travelling against the wind than when moving with it. The Savonius turbine spins due to the drag.

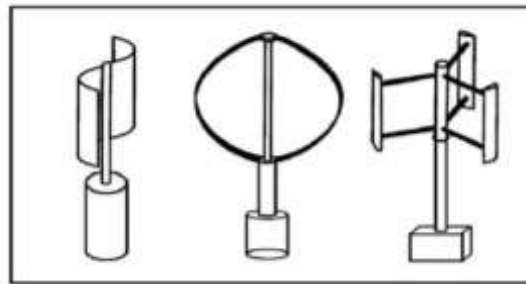


Figure 3: Vertical Axis Wind Turbines.

PRINCIPLE OPERATION

Aerodynamically, the Savonius rotor is a drag-type device with two or three scoops. When viewed from above the two-scoop machine, the rotor would resemble an "S" form in a cross-section. Because of its design, it feels less drag while travelling against the wind than when moving with it. The drag causes the Savonius turbine to rotate. Because they are drag-type devices, they separate far less of the wind's capacity than other comparable estimated lift-type turbines.

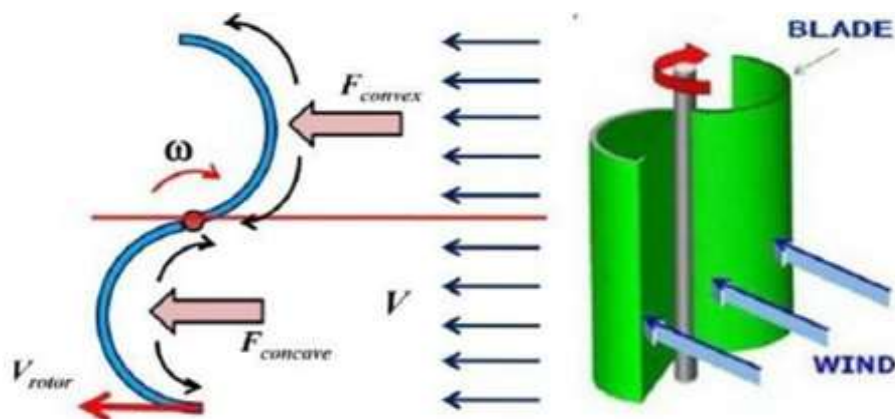


Figure 4: Principle Operation

Table: 1

List of Materials Used		
Sl. No	Components	Materials
1	Blade	Galvanized Iron
2	Cover Plate	Plywood
3	Shaft	Mild Steel
4	Bearing	Stainless Steel

MAIN COMPONENTS

Blade

A blade is composed of sheet metal gauge, and as the gauge number grows, so does the material thickness. Sheet metal materials are classified into two types: galvanized steel and aluminium.



Figure 5: Galvanized Steel

Cover Plate

The cover plate of our VAWT plywood is 5mm thick.



Figure 6: Plywood

Pillow Block Bearings

Pillow block bearings are used to make rotation easier. Bearings minimize friction by providing smooth metal balls or rollers, as well as a smooth inner and outer metal surface for the balls to roll against.



Figure 7: Pillow Block Bearings

Shaft

Because of the thickness of the pipe, the shaft is built of steam line pipe, which has high strength. It is constructed of mild steel, which is appropriate for welding and drilling.



Figure 8: Steam Line Pipe

DESIGN CALCULATIONS

The wind turbine operates on the premise of transforming wind kinetic energy into mechanical energy. Any particle's K.E. is equal to one-half of its mass multiplied by the square of its velocity, or $\frac{1}{2} mv^2$.

Blade arc angle

$\emptyset = 180^\circ$ (classical type)

Design of end plate

$D_o = 10\%$ Greater than D

$D_o = 0.66 \text{ m}$

Blade Diameter and Height

From a reference journal book, It is suggested that the ideal aspect ratio is $\alpha 0.77$. It improves rotor performance.

Table: 2

K.E.	$= \frac{1}{2} mv^2$ (1)	
K.E	=	kinetic energy
m	=	mass
v	=	velocity,

M is equal to Volume multiplied by its density ρ of air,		
Mass	=ρ AV (2)	
Substituting Eqn (2) in Eqn (1) We had got,		
K E	=	½ ρ A ³ watts

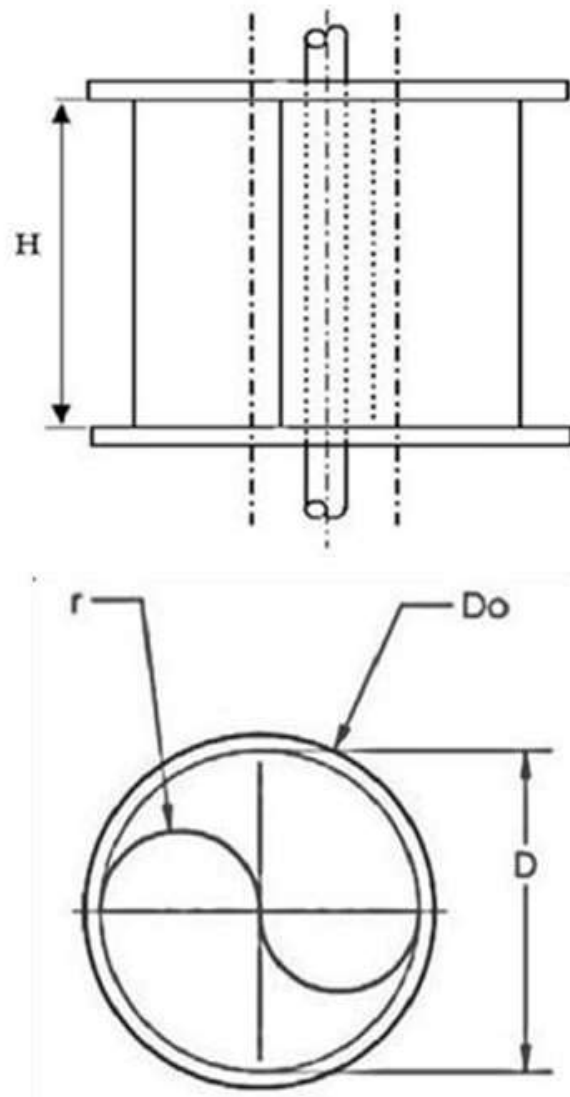


Figure 9: Representation of Basic Dimension

PERFORMANCE CALCULATION

Wind velocity $u = 5 \text{ m/s}$ Power $P = 0.5 \times C_p \times \rho \times A \times u^3$ Tip speed $\lambda = U_{\text{tip}}/u$

$$\omega = 2\pi N/60$$

Angular velocity

Table: 3

α	=	H/D $\rightarrow$ (1)
α	=	0.77(i.e.)
α	=	77%
Considering		
D	=	0.6 m
Then height h will be found from equation $\rightarrow$ (1). Substitute α and D above		
equation $\rightarrow$ (1).		
0.77	=	H/0.6
H	=	0.462 m
considering the overlap ratio		
a/d	=	8.2%
a/d	=	8.2%
a	=	0.082/0.3
a	=	0.024 m

The shaft diameter a is 0.024m we choose 0.02m diameter of hollow shaft (seamless steam line pipe) We prefer hallow shaft over solid shaft due to weight consideration of shaft Blade thickness.

The blade is made up of 26 gauge sheet metal. From the standard chart thickness of 26 gauges is

$$t=0.552 \text{ mm}$$

$$\text{Torque } T = P/\omega$$

Where,

Density of air $\rho = 1.225 \text{ kg/m}^3$ Diameter of Rotor $d = 0.6 \text{ m}$ Height of Rotor

$$H = 0.46 \text{ m}$$

Belt's constant $C_p=0.4$ Diameter of the rotor

$$D = (2d)$$

$$D = 0.6 \text{ m}$$

Radius of the rotor

$$r = D/2$$

$$r = 0.3 \text{ m}$$

$$\text{Area } A = D \times H$$

$$A = 0.6 \times 0.462$$

$$A = 0.277 \text{ m}^2$$

$$\text{Power } P = 0.5 \times C_p \times \rho \times A \times u^3$$

$$P = 1/2 \times 0.4 \times 1.225 \times 0.277 \times 53$$

16.96 Watt (for double stage $P = \text{rotor}$) Where

ρ	The density of air (kg/m^3).
A	Swept Area (m^2).
u	Velocity (m/s).

$$\text{Tip Speed ratio } \lambda = U_{\text{tip}}/u$$

$$\text{Consider } N = 300 \text{ rpm}$$

$$U_{\text{tip}} = (N \times 1) / (60 \times 2\pi r)$$

$$U_{\text{tip}} = (300 \times 1) / (60 \times 2\pi 0.3)$$

$$U_{\text{tip}} = 9.42 \text{ m/s} \text{ Tip Speed ratio } \lambda$$

$$= 9.42/4$$

$$\lambda = 3.142$$

Angular velocity $\omega = (2\pi N)/60$ $\omega = (2\pi \times 300)/60$

$= 31.42 \text{ rad/sec}$

Torque $T = P/\omega$

$T = (16.96/31.42)$ T

$= 0.538 \text{ Nm}$

Diameter (D) = 0.6 m

Height (H) = 0.48 m

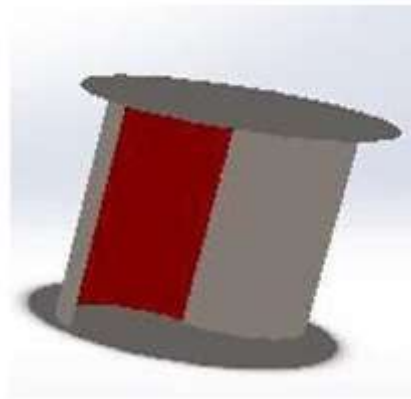


Fig. 10: Assembly View of Savonius Rotor

ADVANTAGES

- Axis Vertical Wind Turbines may be operated in any wind direction. It is simple to fabricate and does not.
- Higher winds are required; however light winds may also be operated easily.
- The producing unit is positioned lower to the ground to facilitate maintenance if necessary.
- More secure operation. It has a lower wind speed limit than horizontal turbines.
- It also reduces the danger of hurting birds and reduces noise levels.
- Installation is significantly simpler compared with traditional types. It may be immediately placed on a rooftop.

APPLICATION

- This turbine may also be installed alongside high-speed train tracks to increase energy output.
- A savonius turbine on a communication tower.

CONCLUSION

The two-bladed rotor outperforms the three- and four-bladed rotors in terms of productivity. The rotor with end plates performs better than those without end plates. The execution of a double-stage rotor is more conspicuous than that of a single-stage rotor.

As the rotor stages grow, so does the wind turbine's coefficient of performance. A solar panel may be installed on the system, increasing its efficiency significantly.

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