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# Savonius Vertical Axis Wind Turbines: A Review of Design Principles and Fabrication Approaches

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***Abstract***

*The need for renewable energy-based applications is rising in the modern world. The wind turbine is among the most practical energy sources. The best examples of using wind energy to its fullest extent are windmills. One such use for wind energy harvesting is the "Vertical Axis Wind Turbine" project work. In this project, the possibility of producing electricity and supplying it to bus stops, traffic lights, streetlights, etc. was investigated. This turbine would serve as a renewable energy source by producing high-velocity wind when it was erected next to motorways and flyovers. This turbine will use a Savonius blade to lessen air drag. Fibre is used to build blades, so they are lightweight and flexible. It has a DC motor and a spur gear system. This advancement makes producing electricity simple and affordable. As a result, a prototype for a workable arrangement has been created.*

**Keywords:** Lift and drag coefficients, Wind Turbine, Wind Energy, Renewable Energy, Electricity Generation, Design of Blades, Efficiency of VAWT

## INTRODUCTION

The cylindrical structure of most wind turbines is made of steel tubing and has three blades attached to it. Less popular variations include those with two blades and/or towers made of concrete or steel lattice as shown in Figure 1. By raising the turbine 100 feet or more above the ground, the tower enables it to take advantage of the stronger winds that are found at higher altitudes.

One kind of vertical-axis wind turbine (VAWT) that was developed in the early 20th century is the Savonius wind turbine as shown in Figure 2. Sigurd Johannes Savonius was an engineer who invented these basic turbines. The airfoils of Savonius wind turbines are shaped like scoops and typically have two or three of them. By capturing wind, these scoops provide drag power to turn the turbine. Even though three or more scoops have great drag power to get a turbine moving, a Savonius wind turbine can only run as fast as the wind that is blowing past it. The Savonius wind turbine's height is another element that contributes to its slower operating speed. Its design typically places it lower to the ground than other wind turbines. Wind speeds are highest in the air and lowest near the ground. This indicates that alternative vertical wind turbine types that are taller and accelerate with lift power—like Darrieus wind turbines—are typically better at producing significant amounts of electricity. The advantage of Savonius wind turbines over Darrieus wind turbines is that the former are typically more

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affordable and robust. People have been using wind energy for everything from sailing around the world to grinding grain in windmills. Three essential components make up a wind turbine: a generator, blades, and tower. Together, these components transform wind energy into electrical energy. With the usage of wind turbines, wind is being increasingly widely used as a clean, renewable energy source today. Electricity produced by the generator's rotation can be utilised to light electrically powered devices. Savonius wind turbines are excellent for producing electricity in both urban and rural areas, as well as for supplying extra power to land and marine vehicles. However, they are particularly helpful for producing smaller amounts of electricity in places where regular maintenance will be difficult or where the wind turbine will need to be exceptionally powerful due to extreme conditions. Savonius wind turbines, for instance, are found in regions like the Antarctic and the Sahara Desert, where conditions are harsh, suitable transportation is scarce, and wind turbine specialists aren't always readily available to fix turbines when issues occur.

**Wind Energy**

The planet is heated unevenly by solar energy, which produces wind. Because of the pressure variations brought on by this unequal heating, wind is produced. A wind turbine can then use this wind to generate energy. A generator attached to the shaft of a wind turbine spins as the wind pushes its blades, producing electricity that may be fed into the grid and used to power homes. Although they are a green way to produce electricity, wind turbines nevertheless have a lot of serious drawbacks. One issue is that they are very expensive to build and install and need room for wind farms in order to produce adequate energy for towns and cities.

**Project Definition**

The primary goal of this project is the development and construction of a wind turbine that uses Vertical Axis Wind Turbines (VAWT) to transform wind energy into useable electricity. The best sources of electricity that can apply the idea of environmental sustainability to renewable energy include rivers, wind, and solar power. The prime aspect of wind energy is that it is available 24 hours a day, unlike solar energy, which can only be used with sunlight, and hence wind turbines can work throughout the day. The effective, optimum, and ecologically friendly use of renewable energy is another aspect of sustainability. Public spaces such as streets, playgrounds, educational institutions, and facilities are regarded as the primary consumers of power. The idea behind this project is to employ VAWT to turn wind energy into useful energy so that it can be used as a power source for these customers.

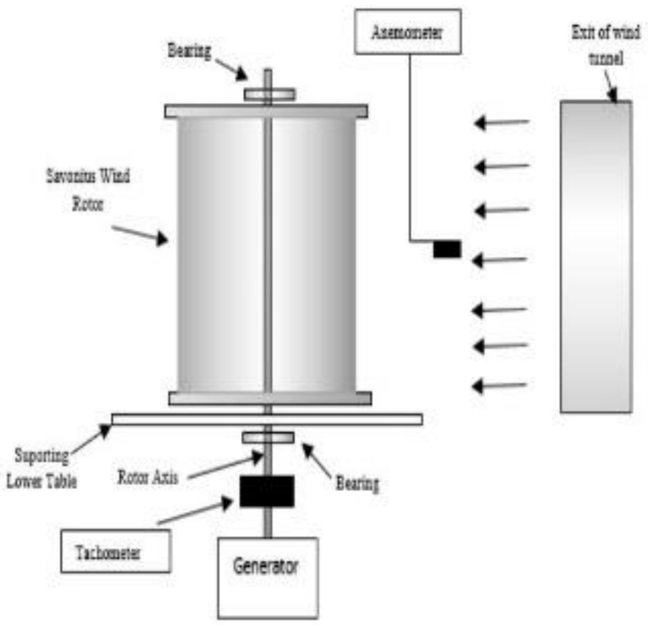



**Figure 1.** Experimental Setup.

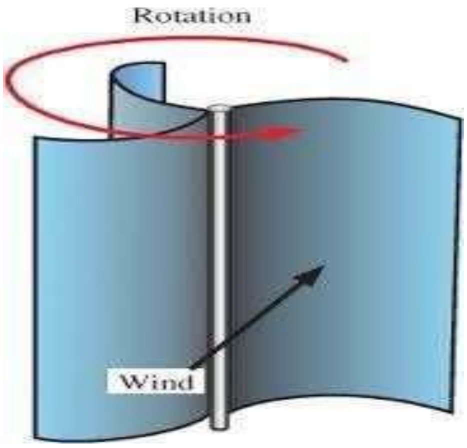



**Figure 2.** Savonius Wind Turbine.

**SAVONIUS WIND TURBINE**

In high-reliability, low-efficiency power turbines, a Savonius vertical-axis wind turbine is a slowly rotating, high-torque device with two or more scoops. The Savonius wind turbine employs drag, which prevents it from rotating faster than the wind speed that is approaching, whereas other wind turbines use lift produced by airfoil-shaped blades to drive a rotor.

Savonius wind turbines are distinguished in the field of wind energy generation by a number of special characteristics and benefits that come with their unusual vertical axis design. Savonius turbines have drawn attention for their usefulness in a variety of applications due to their straightforward design and capacity to function well in low wind situations.

Savonius turbines rotate on a vertical axis, in contrast to conventional horizontal-axis wind turbines (HAWTs). They can catch wind from any direction because to this design, which eliminates the need for intricate yaw mechanisms. Because of this, they are less susceptible to turbulence and variations in wind direction, which makes them perfect for urban and built-up situations with erratic wind patterns. The torque and rotational motion produced by Savonius turbines are derived from drag force. As the wind passes over the turbine's curved blades, an uneven pressure distribution is produced. The turbine shaft is driven by the blades' rotation due to the pressure differential. In contrast to lift-based turbines like conventional horizontal-axis designs, the drag-based operation streamlines the design and production process. Savonius turbines stand out for its capacity to start themselves at low wind speeds. They are appropriate for areas with moderate or variable wind patterns since their design naturally allows for rotation even in mild gusts. Continuous power generation is ensured by its self-starting ability, particularly in locations where wind speeds are insufficient for other turbine types. Savonius turbines have a simple design with just three main parts: support structures, a central shaft, and curved blades. Because of its simplicity, it is easier to fabricate, install, and maintain, which lowers both the initial cost and ongoing operating expenses. Savonius turbines are also resistant to severe weather and mechanical pressures because of the design's durability.

Savonius turbines can be found in a range of sizes, from small-scale installations ideal for home use to bigger ones for commercial and industrial use [2]. Their scalability permits customisation based on site-specific conditions, available space, and energy requirements, allowing for flexibility in deployment. Savonius turbines can also be included into hybrid renewable energy systems or used to supplement current power sources.

When viewed from the top, its shape resembles a “S”. These rotors can be employed in single- or multi-staged setups and can have two, three, or more bladed systems. The difference in drag force between the convex and concave portions of the rotor blades as they rotate around a vertical shaft is the basis for the operation. This was picked due to its straightforward construction and ability to start on its own even in light winds.

A savonius wind turbine's blades are constructed in a helix shape surrounding the vertical shaft. This blades' wind-receiving surface is solid and wide. The most important characteristic of a Savonius wind turbine is this. When in operation, a flow resistance mechanism is used by Savonius turbines to turn their rotors. Hence, the dynamic pressure of the wind acts against the blades and causes the rotor to rotate. At the same time, an aerodynamic resistance or drag force is encountered on the opposite side of the blades. Savonius wind turbines can only rotate as quickly as the wind as a result. The design makes use of two overlapping half-cup designs, which is highly advantageous for wind turbine design. The Savonius design offers several attractive features, including low operating velocity, low noise, and ease of construction at a low cost. It is designed in such a way that it can access wind from any direction and is capable of withstanding extreme weather conditions without significant damage. Furthermore, the design has several modifications that alter the turbine's performance based on the arrangement of the blades.

**Operational Perspective of Fabrication**

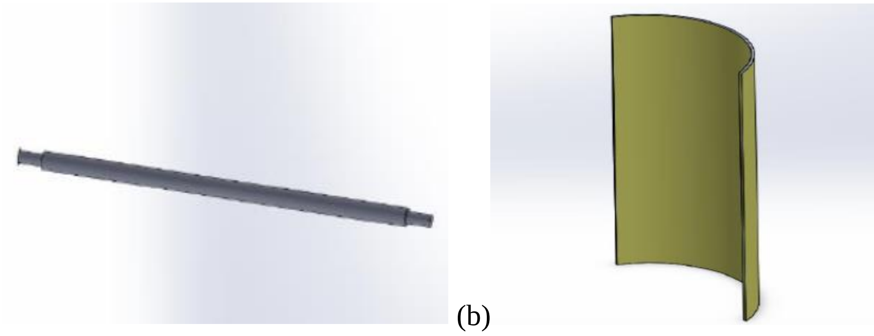
Among the simplest rotors is the Savonius turbine. It is a drag-type structure from an aerodynamic perspective, with two or three scoops. In cross-section, a two-scoop machine could look like the letter “S” when viewed from above, looking down on the rotor. The scoops move against the wind with less drag than when going with the wind because of their curvature. The Savonius turbine rotates due to differential drag. Savonius turbines draw far less power from the wind than other turbines of a similar size that are lift-type since they are drag-type devices. If a Savonius rotor has a short mount without an extended post, a large portion of its swept area may be close to the ground. This reduces the effectiveness of the energy extraction process overall because of the slower wind speeds.

**Analysing and Modelling Designs**

Cad Drawing with Solidworks, every component is modelled. The overall amount of electrical power that has to be generated determines the physical dimensions of each constituent. Figure 3 displays the shaft and blade cad models.

Here is the assembly arrangement of components in CAD modeling presented in Figure 4. According to Roy and Saha's review research, a Savonius rotor's design, performance, and efficiency can all be considerably improved by using the right computational approach [5].

A preliminary assessment of the viability of constructing integrated wind turbines, as well as the encouragement of the integration of renewable energy sources into newly constructed and renovated buildings and the promotion of micro-scale power generation in urban settings, were all offered by Gagliano et al. The created approach makes it possible to quickly and accurately calculate the annual energy production that micro-wind devices can produce, which in turn makes it possible to create a usable database on the GIS platform that gives the wind distribution within an urban area [3].



(a) (b)

**Figure 3.** CAD model (a) Shaft (b) blade.

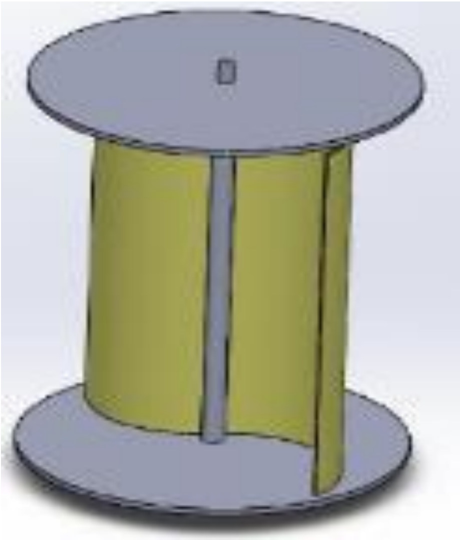


**Figure 4.** Assembly of CAD Modeling (Source: [10]).

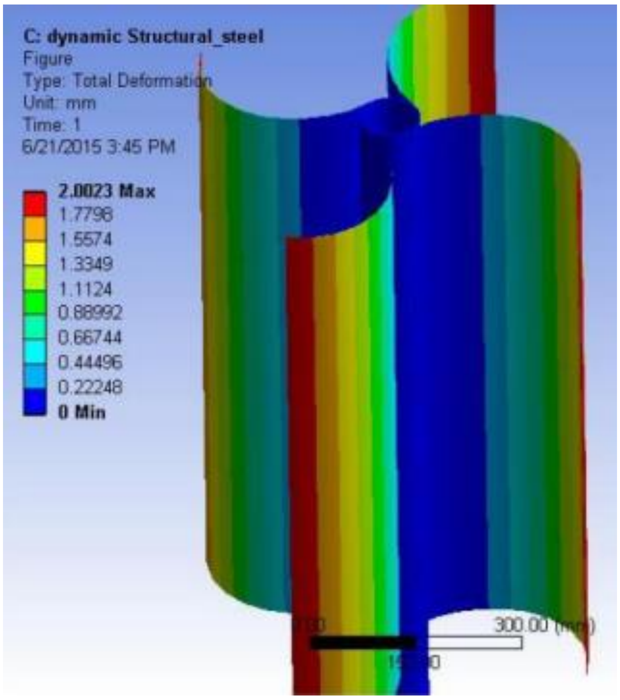



**Figure 5.** Total Deformation in blades [1].

**Applied Procedure for Savonius VAWT**

The average monthly power use of a home is calculated. According to that the percentage of electricity that VAWT will contribute to the home estimated. The turbine size needed for that kind of power generation is calculated as per the requirements. The following values have been considered for designing savonius wind turbine as. D = 2.5 mA = 3m, H = 7.5 $m^2$, Cp = 0.3, $\lambda = 1$, $\rho = 1.22$, V = 9 m/s

Using computation to guide the turbine rotor design. Multistage hand-made permanent magnet generator design implemented. Considering additional components based on rotor size, such as the bearing, shaft, base, disc, magnet, and coils Vertical axis wind turbine CAD model prepared as shown in Figure 3. Examination of the created model as different aspects included. Manufacturing of the VAWT as per the defined as shown in Figure 5. Examining it in various wind conditions and compared its findings and evaluated.


**Figure 6.** VAWT prototype.

## FABRICATION OF TURBINE BLADES

The most crucial and fundamental component of a wind turbine is its Savonius blades. They are composed of certain materials, such as carbon fibre, fibre glass, or aluminium. High Impact Polystyrene, which has a high batter strength-to-weight ratio, is used in this instance as the blade material. The way each individual blade is created can have an impact on the rotor's overall design. The hub rotates because of the rotor blades, which harness wind energy and transform it into kinetic energy. On VAWT working at low blade-speed ratios, zero-net mass flux actuation can result in lower oscillatory loads and more robust output power [6–7]. We bent the 10 cm plate into a curved shape. After that, we punched two holes for the cables to go through and secured them in place. One fabricated system shown in Figure 6.

The following formula can be used to determine the aerofoil's half thickness, or elevation above or below the axis of symmetry:

$$y = \frac{t}{0.2} c \left[ 0.2969 \sqrt{\frac{x}{c}} - 0.1260 \left(\frac{x}{c}\right) - 0.3516 \left(\frac{x}{c}\right)^2 + 0.2843 \left(\frac{x}{c}\right)^3 - 0.1015 \left(\frac{x}{c}\right)^4 \right]$$

y is the half thickness at a particular value of x (centerline to surface), c is the chord length, y is the point along the chord from 0 to c, and t is the highest possible thickness as a fraction of the chord (thus 100 t yields the last two digits in the NACA 4-digit denomination).

### Shaft

Power is transferred from a particular source to an additional source by means of a rotating machine component known as a shaft. Some tangential force provides the power to the shaft, and the torque that is created inside the shaft enables the power to be transferred to different machines that are connected to the shaft. This project makes use of an aluminium shaft [8]. The design of a shaft is based on the "Maximum Shear Stress Theory." The shaft is often round, although it can also have a square or cross section. They are solid, however hollow shafts are also utilised occasionally. However, we were using a solid round shaft [4]. Moutsoglou and Weng conducted a study comparing the effectiveness of a Savonius rotor with a Benesh rotor as wind power generators [9].

## SPUR GEAR

Spur gear most basic kind of equipment shown in Figure 7. They consist of radially protruding teeth on discs or cylinders. When looking at the gear at a 90° angle to the shaft length of sentence, the tooth faces are straight and parallel to the rotational axis. In general, the cross section of a tooth is not triangular when viewed along the shaft. A curved cross section is required to produce a constant driving ratio. When spur gears are installed on parallel shafts, they mesh properly. Tooth loads do not provide axial thrust. Spur gears make a lot of noise at high speeds, but they are amazing at moderate ones. Spur gears make a lot of noise at high speeds, but they are amazing at moderate ones.

**Figure 7.** 3D Printed spur gear.

The turbine is designed to run at the optimal rotor speed of 70 rpm since it is a drag type turbine, which runs at a lower rpm than other vertical axis wind turbines. This turbine produces 1 KW of power per hour at a speed of 9 m/s, enough to run a self-sufficient dwelling 24/7.Because the wind data was gathered for the website using an emometer rather than from websites that offer wind speed statistics, it is more realistic. It was modelled in Solid Works and evaluated by ANSYS, which employed Solid Works flow tools to conduct an aerodynamic analysis.

**CALCULATIONS**

$P = Cp \frac{1}{2} \rho A V^3$ (1) Standard wind equation (derived from power coefficient analysis)

Given Data: Blade length (L) = 230 mm

Wind speed (v) = 12 m/sec

Air density (ρ) = 1.23 kg/m3

Power Coefficient (Cp) = 0.4

Inserting value for blade length as the radius of the swept area into equation

L= r = 230 mm

$A = \pi r^2$

$= \pi * (230)^2$

$= 0.0322\ m^2$

P(available) = pAV3Cp

P(avail) =0.5*1.23*0.0322*12*12*12*0.4

=13.68 kW

Drag Equation

D= [Cd* ρ *V2*A]/2

where

D=Drag, Cd= Coefficient of drag, ρ= Density, V= Velocity in m/s, A= Reference area

Drag coefficient for flat area surface ;

Cd= 1.28…….( As per Glenn Research Centre)

Today' air velocity as per weather department reported 23 mph.

D= 1.28*(1.165*23*23/2)*0.0322

= 12.70 kg/m for one blade

There are four blades in wind turbine. Therefore, D = 12.70 * 4

= 50.80 kg/m.

For wind power analysis, computational fluid dynamics (CFD) is a useful design technique. Without spending money on physically building multiple turbines with various geometrical configurations, a huge number of simulations can be run, examined, and optimised. The torque and stress on the rotor can indeed be forecasted using CFD simulations. These can subsequently be used for estimating the turbine's performance coefficient. When performing a static analysis, it is necessary to compute the force acting on the blade. Savonius rotor is a drag device, although it also generates some lift force. So, using the blade cross section area as an aero foil, we used cfd analysis to calculate the lift and drag force. Prior to using the inlet, define the boundary condition. The global energy crisis and high global emissions have led to a significant growth in research and development activity in the field of renewable energy, particularly wind and solar. Nevertheless, there is currently insufficient technological design available to create a dependable distributed wind energy converter at low wind speeds. For these circumstances, the Savonius rotor seems very promising, yet it has low efficiency. To date, a great deal of research has been done on Savonius rotors to increase their efficiency. These extensive experiments come with high expenditures and risks. Computational studies have demonstrated in this context how important it is to do research with a vast variety of physical designs and characteristics.

## CONCLUSION

The constructed wind turbine's efficiency was found to be about 30%, with some variance at various wind velocities. When compared to a horizontal axis wind turbine, which has an efficiency of 35%, this is a very good efficiency. The efficiency of VAWTs that are now on the market, albeit with diverse designs, is 17%. Even though the power output appears to be low, it can still be considered useful power. Our high amount of dead weight was one of the causes of the low efficiency. VAWT has a great advantage over HAWT in that they can work at a low height. VAWT can therefore be put on individual homes for their specific purpose. Turbine power can either be stored or utilised to charge a storage device, which can then be utilised as a constant power supply. should concentrate on producing energy where it is most needed, utilising various strategies and sites, protecting the environment, and making a major contribution to societal well-being. Microgeneration technologies, particularly those that rely on renewable energy sources, hold promises for lowering greenhouse gas emissions associated with the built environment while also lowering electricity costs for consumers.

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