DESIGN OF HYBRID VERTICAL AXIS WIND TURBINE

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Abstract - *The ultimate aim of this project is to construct a savonius type of vertical axis wind turbine that will be combined with a solar panel to create direct current (DC) electricity that will be used to charge a battery. This system will meet the house's basic electrical needs. A variety of designs were examined in terms of wind turbine type, and a savonius type wind turbine was selected based on literature study. The final outcome of the project was a 40W vertical axis wind turbine. When combined with a solar panel, the device may generate up to 25 watts of electricity. The major goals of this project are to decrease pollution and preserve the environment by reducing the use of fossil fuels, increasing windmill power output, and developing hybrid machines to create more electricity with zero emissions.*

***Key Words*: Blade, blade material, efficiency, savonius type, generator, inverter circuit, vertical axis wind turbine.**

List of Abbreviations:

1. VAWT – Vertical Axis Wind Turbine
2. HVAWT – Hybrid Vertical Axis Wind Turbine
3. HAWT – Horizontal Axis Wind Turbine

1. INTRODUCTION

Wind energy is the simplest and fastest-growing kind of energy for utilizing current wind resources while reducing non-renewable energy use, which has a variety of negative environmental consequences. Wind energy, in particular, has been extensively used in industrial sectors and has been pushed via financial incentives, as well as being recognized as an important approach for securing long-term energy supply. This project's purpose is to develop and construct a Savonius VAWT. The Savonius type of vertical axis wind turbine (VAWT) is a tiny wind turbine designed for household use, however we focused on installing HVAWT near roads and railway lines for this project. In comparison to HAWT, VAWT needs a lower initial expenditure and less installation area. Power may be created even when the wind speed is low. Wind turbines with a vertical axis are easier to maintain than those with a horizontal axis. Due to its great efficiency, VAWT cannot be used for bigger production quantities. Ground-level power production and simplicity of installation are the key advantages of VAWT over HAWT.

2. LITERATURE REVIEW

Niranjana.S.J et al., [1], investigated the power generation by a combined type of savonius vertical axis wind turbines. A wind turbine is mounted atop a highway bridge in this research to produce electricity. When a car travels over the road at a high speed, the windmill's turbine turns and offers power sources. A vertical axis wind turbine, according to this research, can gather air from every direction and create 1 kilowatt of electricity at a speed of 25 metres per second. A VAWT's efficiency might be improved by changing the blade size and form. The design and manufacture of a vertical axis economical windmill were examined by Abmjit N Roy et al [2].According to this research, the savonius VAWT is one of the most important types of wind turbines. The primary rotor shaft of a wind turbine is vertically linked to the generator and gearbox, which might be located near the ground. Performance factors such as power output vs. the results of the experiments show that placing a wind turbine on top of a building in the best position for generating power is a smart idea. Power production becomes more straightforward, and it is employed for a wide range of applications, including public lighting, residential usage, agriculture, and so on. A review of the literature on blade design and development was undertaken by D.A. Nikam et al [3]. According to this study, windmills, such as vertical and horizontal wind mills, are frequently used for energy production. The horizontal wind mill is often used in large-scale applications that need a great amount of space and money. The vertical wind mill, on the other hand, is cost-effective and suitable for residential usage. A review of integrated vertical axis wind turbines was undertaken by ParthRathod et al [4].Aspect ratio, tip speed ratio, velocity, and other geometric characteristics are used in this study to achieve increased efficiency. The experiment's purpose is to boost a wind turbine's power production and efficiency. To maximize design development, the blade structure and flow performance are merged. The study demonstrates that turbine efficiency is constantly affected by wind speed and weather. The design and construction of a savonius HVAWT were researched by PiyushGulve et al [5]. According to this study, Savonius HVAWT are more efficient than horizontal axis wind turbines since they take up less area and produce less noise while producing the same amount of power. The efficiency of wind turbines may be diminished as a result of manufacturing defects and frictional losses, according to the study's results. It will be corrected by more aerodynamically specifying the blade design.

3. SCOPE OF THE PROJECT

The turbine's design of our project does not need any additional room. Because of the low vibration, structure damage is kept to a minimum. As a consequence, this turbine may be installed in any government, residential, or commercial facility. If we utilize high-grade carbon fibre material, we may install it in high chimneys, on a boat, or at a country's border where power is not available. Due to the fact that this is a new business, there are a variety of ways to improve turbine efficiency. Using a gearbox, the rotational speed may be increased and more power created. It is also possible to set various angles at different speeds of the turbine as a future improvement or scope. Extra electricity will be produced via a solar panel positioned on top of the wind turbine. The majority of our project is focused on the highway and railway lines.

4. NEED FOR THE CURRENT STUDY

- Wind and Solar are abundant sources of energy in India, with highways having a lot of space to install them. So we can use this space to set up VAWT to produce as much renewable energy.
- When there is a lot of space leftover near the railway tracks, VAWT can be installed in those places. So that the nearby villages, Railway Stations can be provided with an uninterrupted source of energy.

4.1 VAWT ADVANTAGES

Turbines with horizontal rotational motors and blades have more components than those with vertical rotational motors and blades. As a consequence, there will be fewer worn-out and failed components. Because the gearbox and generator are close to the ground, the tower's supporting strength isn't as important. Pitch and yaw control components are also unnecessary.

It's also not necessary for the turbine to be pointed in the appropriate direction. In a vertical arrangement, air flowing in any direction and at any speed may spin the blades. As a result, the device can generate energy in both strong and light breezes.

4.2 TOP BENEFITS OVER HORIZONTAL TURBINES

Because of the vertical shape, engineers may be able to position the turbines closer together. A wind farm may be developed on a smaller area of land since they don't have to be as far apart. Horizontal wind turbines in close proximity may generate turbulence and wind speed decreases, decreasing the output of nearby units.

Vertical axis wind turbines produce less energy per tower, but when arranged, they may generate up to 10 times more power across an equivalent amount of land.

4.3 DISADVANTAGES OF VAWTS

Vertical systems' energy production efficiency is restricted since not all of the blades create torque at the same time. Although a turbine can function in high winds, this is not always the case; low starting torque and dynamic stability concerns might restrict performance in situations that the turbine was not designed for.

The wind turbines are unable to collect the greater wind speeds seen at higher altitudes since they are closer to the ground. It will be more challenging for installers who choose to put the structure on a tower. It is more practical to install a vertical system on a level foundation, such as the ground or the top of a building.

Vibration may be a problem at times, and it can even increase the noise output of the turbine. Turbulence may be created by ground-level air movement, which enhances vibration. This may occasionally lead to additional maintenance and, as a consequence, more costs. Previous versions' blades were prone to bending and breaking, causing the turbine to fail. Small units atop buildings or other structures may be exposed to jarring loads, resulting in lateral stress that requires frequent maintenance and the use of more durable materials.

5. TYPES OF BLADE DESIGN

Types of VAWT:

1. Savonius type
2. Darrieus type
3. H-darrieus
4. Helix shape

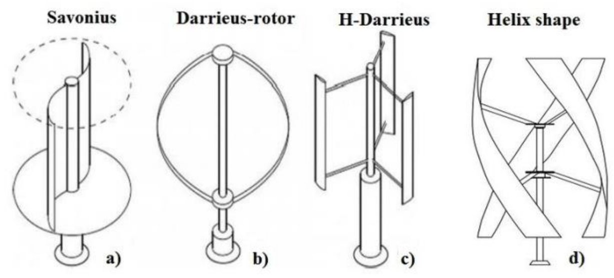

Figure 5.1 *Types of VAWT*

We have chosen the Savonius and Darrieus type as our primary choice because of their simple design and high efficiency. Later we compared both the types of blades with their advantages and disadvantages from table 5.1.

Table 5.1 *Difference between Darrieus and Savonius*

Darrieus Type	**Savonius Type**
Does not rotate automatically	Automatic rotation
The rotor can take wind from every direction, but wind velocity affects the rotation	Always rotates, no matter from which direction the wind blows, the wind velocity also doesn't matter.
Easy installation in buildings	Easy installation near roadways and highways.
Low efficiency	Low efficiency

6. METHOD OF BLADE DESIGN SELECTION

A literature research was utilized to compare several sorts of blade designs, and then each of our team members offered a separate design. To eventually conclude the blade design, we employed a graphical representation with the features and types plotted in it.

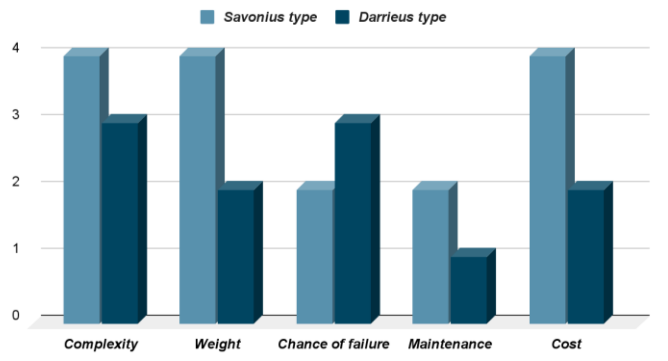

Figure 6.1 *Selection of blade design using graphical representation*

From the above graph we decided to use savonius type blade design because of its simplicity and other mechanical properties.

7. SAVONIUS VERTICAL AXIS WIND TURBINES:

Sigurd Savonius, a Finnish engineer, invented the Savonius wind turbine in 1922. The most basic design is an S-shaped blade with two blades. The Savonius turbine's curved blades are pushed by drag to create a torque that rotates the rotor. In terms of aerodynamics, it is the easiest wind turbine to design and produce, lowering its cost substantially when compared to other VAWTs and HAWTs that employ aerofoil blade designs. It works on a very simple concept.

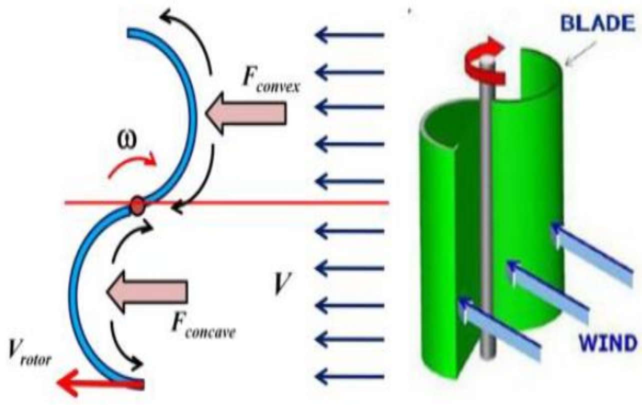

Figure 7.1 *Working principle of savonius VAWT*

The air is trapped in the concave section of the turbine, which propels it forward. Because part of the wind's energy is used to push the convex portion, the turbine's efficiency suffers as a result. The S shape design may be expanded with more blades, and it spins on the same basis as the figure 7.2 below.

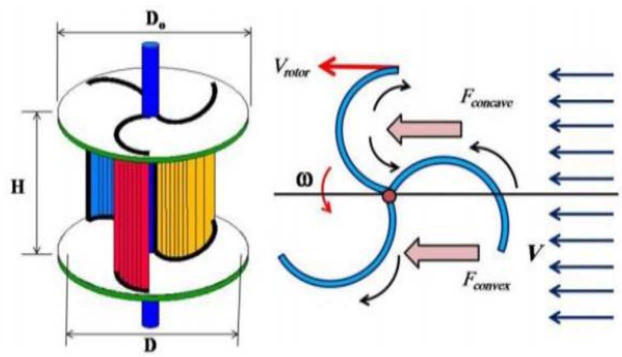

Figure 7.2 *Three blades savonius VAWT*

8. DESIGN

As mentioned above it was planned to design a savonius vertical axis wind turbine. But it was decided to increase the number of blades. So we designed a HVAWT with 6 blades. We hope that this HVAWT with more blades would be helpful in increasing the turbulence while the turbines are installed closer to each other in large numbers. The height of the wind turbine was set at 2metres and the weight is estimated to be around 3.5 to 8.5Kg.

First, we sketched a rough schematic of the wind turbine, including limitations for all of the components we selected from the literature review. Fusion 360 was used to finish the 2d sketching of the hand drawn artwork. Then, using Fusion 360, we began drafting and 3d modelling the 2d drawing. Precision dimensions were given for each component which was subsequently extruded with the appropriate density dimensions.

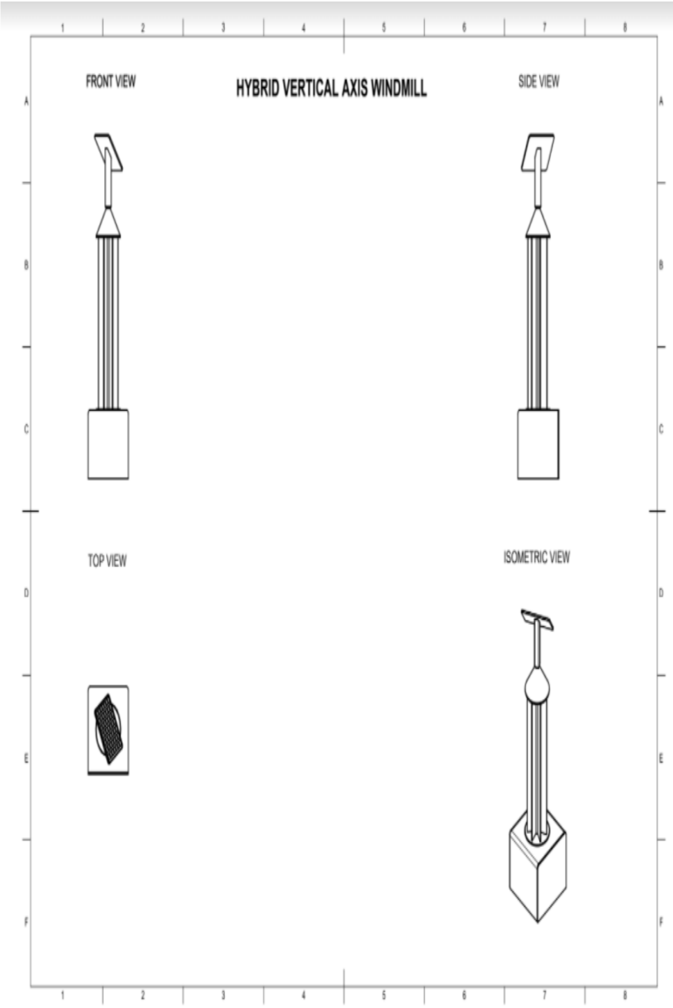

Figure 8.1 *2d sketch of HVAWT*

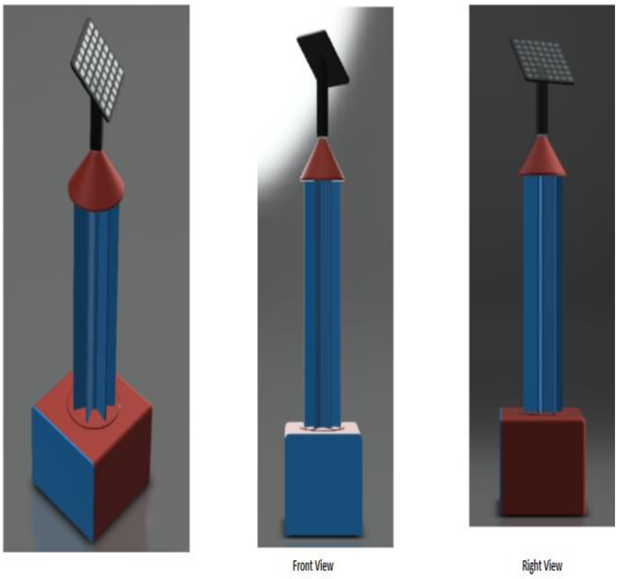

Figure 8.2 *Three dimensional views*

9. COMPONENTS OF THE WIND TURBINE

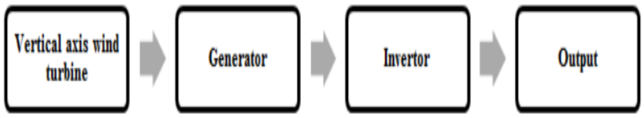

Figure 9.1 *Basic Components of Wind Turbine*

9.1 BLADE:

Newer wind turbines have a low rotational inertia due to the use of plastic and composite materials in their blades, which means they can accelerate fast when the wind comes up, keeping the tip ratio more or less constant. During significant gusts of wind, wind turbines that run closer to their ideal tip speed ratio absorb more energy from sudden gusts that are typical in metropolitan settings. For our design we have used 6 blades.

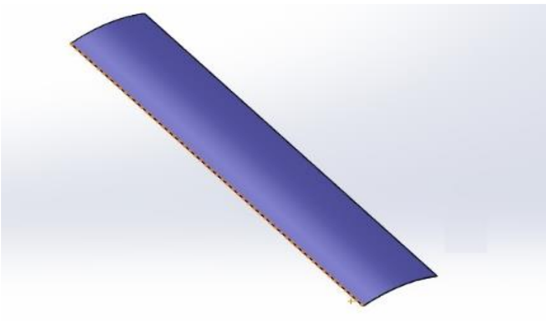

Figure 9.2 *Blade*

9.2 GENERATOR:

The generator is a device that converts the rotational kinetic energy captured by the blades into electrical energy.

9.3 GENERATOR DESIGN:

To achieve the design criteria, we chose to use a permanent magnet DIY generator instead of a prefabricated alternator. This is a PM generator with many stages. This is for enhancing production with a rotor of the same size. The coils form a three-phase connection, which may be stored in a big battery. This kind of generator is often used when a considerable volume of power is required. The graphic below depicts a typical three-phase coil connection for a PM magnet generator.

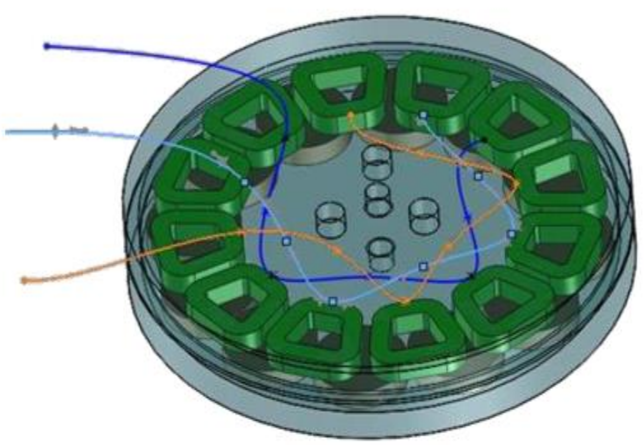

Figure 9.3 *Three Phase connections of 12 coils*

9.4 INVERTER CIRCUIT:

An inverter is a device that converts direct current (DC) to alternating current (AC).

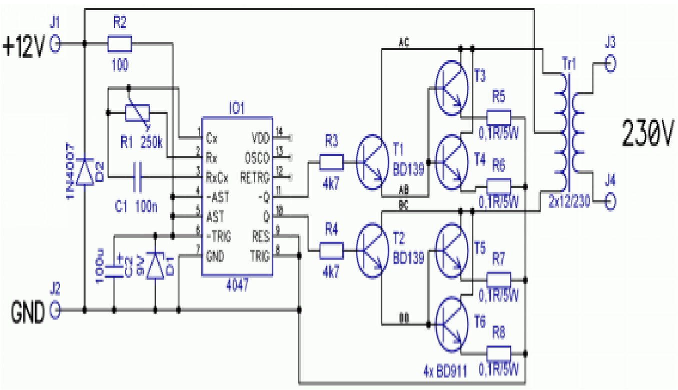

Figure 9.4 *Inverter circuit*

9.5 SOLAR PANEL:

A solar panel is a device used to harness solar energy from the sun and convert it into usable electrical energy. In this type of HVAWT a 10W solar panel is fitted on the top to produce additional electricity along with the VAWT during the day time.

9.6 MATERIAL IDENTIFICATION:

Table 9.1 *shows the advantages of the material selected and the uses of different components.*

Components	Material Identification	Advantages	Uses
Star frame	Aluminium	ight weight orrosion esistant	Top view of the blades
Supporting shaft	Aluminium	ight weight orrosion esistant	For attaching the blades
Blade	PVC sheet/Aluminium	ight weight orrosion esistant	Used to power the rotor of a wind turbine.
L- CLAMP	Aluminium	ight weight orrosion esistant	Attaching the blades with a frame.

10. DESIGN CALCULATION:

The maximum power of a Savonius wind turbine depends upon the height and radius of the rotor and the wind speed. The angular frequency of a rotor is represented by a dimensionless factor called the tip-speed ratio λ. λ is characteristic of a specific windmill, and its value is typically between 0.5 and 14. In a Savonius rotor, λ≈1.

10.1 FORCE CALCULATION:

Area of the rectangular blade A = lxb

= 0.5 x 0.12

= 0.06m^2

Weight of one blade = mass of one blade X 9.81

= 0.0816 x 9.81

= 0.8004 N

Rotational force (lift), Lf =1/2xPxAxV^2 x C_1

=1/2x1.23×0.06×6^2×2.505

Lift force Lf = 3.3276N

Drag force Df = 1/2 xPxAxV^2 x C^2

=1/2x1.23×0.06×6^2×0.04823

Drag force,Df = 0.0640N

Output power,P=F X V

P = 25W

n= Output Power/Input Power

Overall efficiency = **52.27%**

11. FEASIBILITY ANALYSIS:

- With vehicles traveling at 100 Km/hr, the installation of VAWT will surely produce the expected output power and solar energy being abundant on the highways. The VAWT will surely be feasible on the roads.
- When installed near railway tracks with trains running from 100 km/Hr to 160 km/Hr and the solar energy as mentioned above confirms that VAWT is a feasible project.
- For providing enough electricity for charging electric cars in future.
- By setting up in low wind places also we can achieve the required output.

11.1 TURBINE:

Minimum air flow required = 1.2m s^{-1}

Typical Traffic speed = 60mph (approx. 100 kmph)

Residual air flow speed = 5.4m s^{-1} (approx. 12 mph)

Single turbine Capacity = 2.5 kW

Power coefficient = 30 %

Average Daily Output per Turbine: **5.8 kWh**

11.2 SOLAR:

With 10 hours of sunlight

Average Daily Output: **3 kWh**

From the above calculations our hybrid vertical axis wind turbine would be feasible when implemented.

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12. CONCLUSION

The space needed for wind turbine installation will be minimized by integrating vertical wind turbines with solar panels in a single tower. It will gather more wind towers in a smaller area than VAWT and HAWT. Using combined vertical axis wind turbines and solar panels will eliminate the need for fossil fuels and will be very beneficial to the environment in terms of preventing global warming. This project will deliver household current to metropolitan areas, and it is particularly well suited to low-wind places. Because there is a mismatch between the power produced and the demand in Tamil Nadu, this kind of turbine may be used to minimize electricity usage. This effort helps to reduce pollution levels in the atmosphere. It helps to reduce the use of fossil fuels. Throughout the day, both wind and solar power may be used to create electricity. From our study, we were able to draw a number of crucial findings and suggestions that will benefit the development of vertical axis wind turbines in the future. We were able to design a VAWT system that enhanced power generation by 80%.

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