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DESIGN & PERFORMANCE CALCULATION OF VERTICAL AXIS WIND TURBINE

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ABSTRACT
Wind energy is a sustainable and widely available renewable resource, making it a key solution for clean energy generation. This project focuses on the design and performance calculation of a Vertical-Axis Wind Turbine (VAWT) to optimize energy extraction from wind. The study involves the selection of an efficient blade profile, rotor configuration, and structural design to enhance aerodynamic performance. Key calculations include tip-speed ratio, power coefficient, torque generation, and energy output estimation based on wind speed variations.
Structural analysis is performed to verify the strength and effectiveness The findings seek to provide insights into the feasibility of vertical axis wind turbines (VAWTs) for small-scale and urban applications, supporting sustainable energy initiatives. Designing of VAWT is done using SOLIDWORKS software & Calculations are obtained using ANSYS software.

INTRODUCTION
Energy plays an important role in everyday life to carry out any task. The non-renewable energy resources such as oil, coal and gas are majorly used as energy nowadays. The main problem behind the non-renewable energy resources are not sustainable and create global warming which is hazardous to the environment. The renewable energy resources are best way to solve this issue. The renewable energy resources such as solar, wind, tidal and bio gas are available in abundant and sustainable which can be utilized for the requirement. Wind energy is the purest form of renewable energy which is available highly for the production of electricity. Wind is the natural resources which cannot affect the environment. Most of the countries including India understand the importance of wind energy and used as a primary source of renewable energy because of low cost compared to other renewable energy resources. The wind energy is produced by converting the kinetic energy of atmospheric air into mechanical energy. The vertical axis wind turbines are the turbines used to convert the mechanical energy from the kinetic energy.

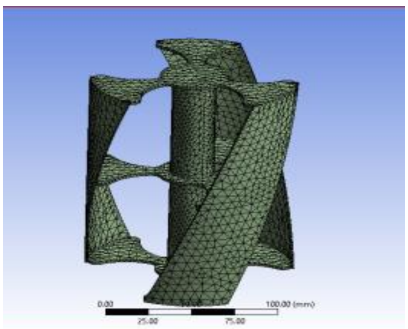

Fig1.Mesh generated with default mesh controls

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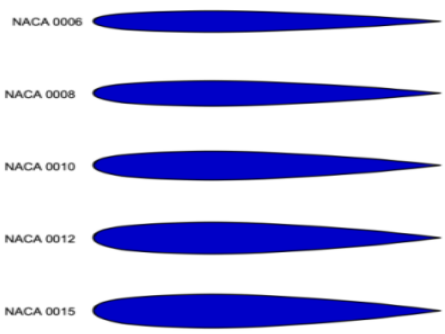

Fig2. *NACA airfoils*

The vertical axis wind turbine (VAWT) is used for domestic purpose and low volume of production. VAWT requires low cost investment and less space for the installation compared to HAWT. The rotational axis of vertical axis wind turbine is perpendicular to the direction of wind. It can produce electricity at low wind speed. The maintenance of vertical axis wind turbine is quite easy compared to horizontal axis wind turbine. The efficiency of VAWT is optimal so it cannot be utilize for larger volume of production. The main advantages of VAWT compared with HAWT are generation of electricity at ground level and the way of installation is simple.

LITERATURE SURVEY

A vertical axis wind turbine (VAWT) is one where the axis of rotation is oriented vertically. VAWTs are capable of generating electricity from winds coming from any direction and operate effectively at low initial wind speeds. These turbines are much quieter than conventional horizontal axis wind turbines (HAWTs), are lightweight, and can be seamlessly integrated into architectural designs. Most of these turbines function primarily through aerodynamic drag forces, with the exception of Darrieus types. Research on these turbines is concentrated on enhancing their aerodynamic performance by minimizing drag and maximizing lift. It has been anticipated that they may serve as an effective energy solution in densely populated regions where wind patterns are unpredictable.

In 1920, Finnish engineer Savonius created this kind of turbine, mainly relying on drag force. This is the most basic wind turbine with a low cut-in wind speed, typically comprising two half cylinders oriented in opposite directions to create a nearly S-shape (Fig.1). One major limitation of this design is its relatively poor aerodynamic performance compared to other turbine models. The Savonius turbine may be more advantageous when power reliability is prioritized over turbine efficiency or cost of energy (COE). Significant efforts have been directed toward enhancing the Savonius turbine's efficiency in urban settings, which includes modifications to the rotor design, blade shape, blade overlap, and the quantity of blades. These turbines are unique in their rotor design and the way they generate torque. The power coefficient varies based on the configurations of rotor design. Unstable. The designs of vertical axis wind turbines (VAWT) can be classified into two categories: Savonius and Darrieus.

The Savonius rotor represents another classic design of vertical axis wind turbines (VAWTs). As previously noted, the Savonius rotor operates as a drag-type device and is made up of two or more blades. These turbines have gained some acceptance because of their low cut-in wind speeds and ability to start on their own, but they experience challenges with low rotational performance and overall efficiency. Akwa et al. conducted an in-depth analysis of Savonius turbines and found that having a variety of rotor configurations is a beneficial feature of this type of machine. The aerodynamic performance is influenced by the rotor's geometry, airflow characteristics, and specific operational conditions. The power coefficient for various Savonius designs ranges from 0.05 to 0.30. Roy and Saha examined the methods for evaluating the performance of these turbines and concluded that computational techniques can effectively enhance Savonius design at a low cost. Additionally, efforts have been made to boost aerodynamic efficiency. The analysis included alterations in blade shape, size, and orientation. It was suggested that choosing suitable computational methods could enhance the design, aerodynamic efficiency, and power coefficient.

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OBJECTIVES

The main objective of this analysis is to evaluate and compare the dynamic and structural behavior of vertical axis wind turbine models under varying vibration and loading conditions. One of the primary objectives is to determine the natural frequencies and mode shapes of models to prevent resonance, which could lead to structural instability. By assessing their deformation under modal and static loads, researchers can identify critical regions that may require design modifications to maintain mechanical integrity. Additionally, evaluating stress and strain distribution helps determine which model withstands mechanical loads more effectively, while fatigue life analysis provides insights into long-term durability. Damage assessment further highlights potential failure points that may need reinforcement, ensuring the models meet performance and reliability standards.

Research and development focused on Savonius Vertical Axis Wind Turbines (VAWTs) primarily seeks to improve their performance, particularly addressing their relatively low efficiency while leveraging their natural advantages. The main goals include significantly increasing the power and torque coefficients through careful optimization of the blade design, encompassing aspects such as shape, number, overlap ratio, and the thoughtful incorporation of aerodynamic enhancements like fins or guide vanes. Additionally, researchers aim to obtain a better understanding of the turbine's aerodynamics using advanced computational fluid dynamics (CFD) and thorough experimental validation, with the objective of minimizing drag and turbulence to enhance energy capture, especially in complicated wind conditions like those encountered in urban areas.

In addition to enhancing efficiency, an important goal is to customize Savonius VAWTs for specific uses such as operation in low wind speeds, small-scale distributed power generation, and their integration into hybrid renewable energy systems. This entails taking advantage of their ability to capture wind from any direction, their self-starting features, and their low noise and vibration levels to ensure suitability for residential and remote locations. The ultimate aim is to tackle existing challenges such as material longevity and manufacturing expenses, thereby establishing Savonius VAWTs as a more viable and widely accepted solution for sustainable energy, particularly in scenarios where their unique characteristics provide a clear benefit.

METHODOLOGY

Methodological approach for the study, design, or evaluation of a Vertical Axis Wind Turbine (VAWT). This can be applicable to small-scale models, simulations, or full-scale implementations:

1. Problem Identification & Goals
• Establish the objective: for instance, enhance efficiency, examine aerodynamic performance, or construct a prototype.
• Select the type of VAWT:
o Darrieus (lift-driven, such as H-type or eggbeater)
o Savonius (drag-driven)
o Hybrid
2. Site Evaluation & Wind Resource Analysis
• Gather wind information (speed, direction, turbulence) for the proposed site.
• Employ tools such as:
o Anemometers
o Meteonorm/Wind Atlas
o Weibull distribution for modeling wind speed
3. Turbine Design Considerations
• Blade count
• Blade geometry: e.g., NACA 0015 (symmetric for Darrieus types)
• Aspect ratio (height in relation to diameter)
• Material for blades & structural design
• Tip Speed Ratio (TSR): An ideal range for Darrieus typically falls between 4–6
4. Aerodynamic Simulation
• Implement Blade Element Momentum Theory (BEMT), Double Multiple Streamtube Model, or Computational Fluid Dynamics (CFD)
• Calculate:
o Power coefficient (Cp)
o Torque

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o Forces acting on the blades
5. Mechanical & Electrical Engineering
• Shaft, bearings, and support framework
• Generator type (e.g., permanent magnet generator)
• Gearbox (if necessary)
• Power electronics along with energy storage or grid integration
6. Prototype Manufacturing
• Construct the turbine according to design specifications
• Utilize materials like aluminum, fiberglass, or carbon fiber
• Ensure balance and structural soundness
7. Testing & Verification
• Conduct wind tunnel assessments or field experiments
• Measure:
o Output power
o Efficiency (Cp)
o Start-up speed
o Vibration and noise levels
8. Data Evaluation & Enhancement
• Review findings to refine design
• Apply optimization methods (e.g., genetic algorithms, parametric sweeps)
9. Documentation & Reporting
• Record methodology, calculations, simulation arrangements, and outcomes
• Provide graphs for Cp versus TSR, wind speed compared to power output, etc.

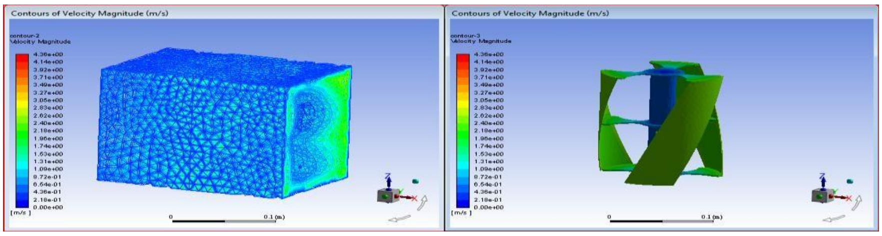

Fig3 .Contours–Velocity

RESULTS AND DISCUSSION

Static Structural and Dynamic Structural Examination

Table 1: Power and Torque of the proposed wind turbine for various wind speedss

S.NO	Wind Speed (m/s)	Angular Speed (rad/s)	Rotational Speed (rpm)	Pmax (watts)	Torque (N-M)
1	10	20	191	369.85	19.23
2	11	22	210	483.51	23.51
3	12	24	229	628.01	27.65
4	13	26	249	797.23	30.95
5	14	28	268	996.56	36.12
6	15	30	288	1242.1	41.46

The table indicates that as the wind speed rises from 10 to 15 m/s, there is a consistent increase in both angular and rotational speeds. In addition, the maximum power output (Pmax) and torque also show an upward trend. Power shows a notable increase, climbing from 369.85 W at 10 m/s to 1242.10 W at 15 m/s, which suggests a nonlinear relationship with wind speed. Torque rises steadily as well, demonstrating greater

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mechanical force with higher wind speeds. In summary, the data demonstrates a strong positive relationship between wind speed and the performance metrics of the turbine.

Table 2: Load and Stress (Mpa)

Load	AL R300	AL R350	AL Twisted
500	55.65	62.81	101.18
1000	112.68	170.25	202.72
1500	169.47	400.1	304.86
2000	226.63	725.80	404.52

The stress levels rise with increasing load across all aluminum samples (R300, R350, Twisted). AL R350 demonstrates the highest stress response, particularly under greater loads, reaching up to 725.80 MPa at 2000N. AL Twisted shows intermediate strength, exceeding R300 at lower loads but falling short of R350 at higher loads. AL R300 consistently displays the lowest stress, signaling the least strength among the three. The rate of stress increase is nonlinear, especially for R350, indicating varying material behavior under load.

Table 3: Load and Strain

Load	AL R300	AL R350	AL Twisted
500	0.001124	0.003105	0.0013514
1000	0.00242	0.004310	0.0027018
1500	0.00365	0.005429	0.0040623
2000	0.00471	0.007324	0.0054020

The stress levels rise with increasing load across all aluminum samples (R300, R350, Twisted). AL R350 demonstrates the highest stress response, particularly under greater loads, reaching up to 725.80 MPa at 2000N. AL Twisted shows intermediate strength, exceeding R300 at lower loads but falling short of R350 at higher loads. AL R300 consistently displays the lowest stress, signaling the least strength among the three. The rate of stress increase is nonlinear, especially for R350, indicating varying material behavior under load.

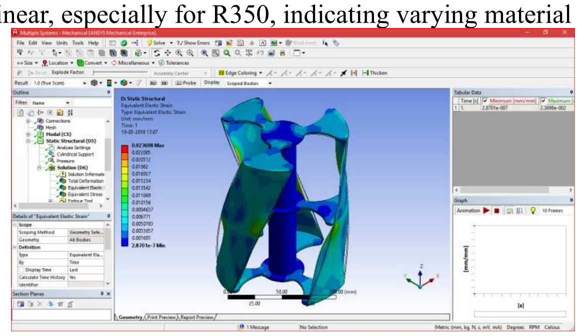

Fig4. Equivalent strain of the vertical turbine and its selection view

Table 4: Load and Deformation (mm)

Load	AL R300	AL R350	AL Twisted
500	56.460	62.795	101.201
1000	112.97	172.61	203.72
1500	169.41	399.79	303.56
2000	226.19	725.23	403.54

The data illustrates stress values (or a comparable metric) for AL R300, AL R350, and AL Twisted as loads increase. As the load rises, all materials typically display an upward trend in the recorded values, indicating their reaction to the applied force. AL R350 consistently demonstrates the highest values under greater loads, implying that it is experiencing the most considerable change or highest stress. Conversely, AL R300 presents the lowest values across all load levels, suggesting a more restrained or lesser reaction to the load. The material

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labeled "AL Twisted" reveals a moderate response, generally surpassing AL R300 yet remaining lower than AL R350.

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CONCLUSION

The Design of VAWT is hence created using SOLIDWORKS and the Analysis is performed in ANSYS. The Blade Profile used is NACA0015. Material assigned to VAWT is Aluminum alloy named Aluminum R350 mm.

{NACA(National Advisory Committee for Aeronautics) blades, or more precisely NACA airfoils, are standardized airfoil shapes developed by the US agency, NASA, and used in the design of aircraft wings and wind turbine blades, known for their efficient lift generation and low drag.}

From both the structural and modal analysis results, it is found that aluminum is suitable for fabrication of wind blades with less weight and low cost without affecting its performance and stability. By comparing all the three different shapes of the blades, it is decided that Aluminum R350 mm is better choice for the fabrication of the wind blade.

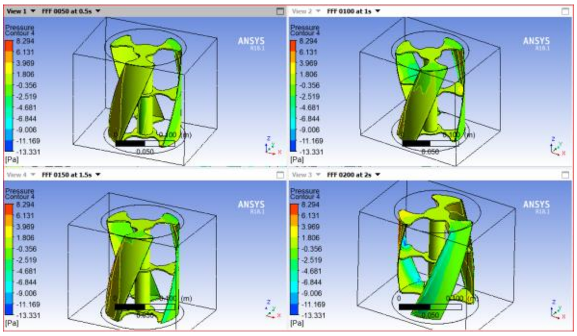

Fig5. Contour- pressure in vertical

In this project, computational fluid dynamics (CFD) is utilized to assess the steam flow of air around the turbine blades. From the analysis of transient structures, we can characterize the deformation and stress based on variations in material properties. Likewise, through the computational fluid dynamic analysis, we can examine the airflow, the direction of air vectors, and both pressure and velocity in relation to changes in RPM. In this project cfd process is involved to determine to find steam flow of the air around the turbine wings. From the transient structural analysis we can defined the deformation and stress as per the change of material properties. And from the computational fluid dynamic analysis, we can define the flow of air flow, vector direction of air, pressure and velocity as per the change of rpm's. The Modeled vertical axis savonius wind turbine can produce electric power of 363 Watts at wind speed of 10 m/s and 1225 Watts at an average wind speed of 15 m/s and it is suitable for houses in urban areas to produce electric power with available wind energy.

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REFERENCES

1. Niranjana.S.J, Power Generation by Vertical Axis Wind Turbine, International Journal of Emerging Research in Management &Technology ISSN: 2278-9359, Volume-4, Issue-7, 2015. Niranjana.S.J, Power Generation by Vertical Axis Wind Turbine, International Journal of Emerging Research in Management &Technology ISSN: 2278-9359, Volume-4, Issue-7, 2015.
2. Mr.Abhijit N Roy, Mr.SyedMohiuddin, Design and Fabrication of Vertical Axis Economical wind mill, International Journal on Recent and Innovation Trends in Computing and Communication, ISSN: 2321-8169, Volume: 3 Issue: 2, 133 – 139, 2015.
3. D. A. Nikam, S. M. Kherde, Literature review on design and development of vertical axis wind turbine blade, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, 156-161, 2015.
4. Altab Hossain, A.K.M.P. Iqbal, Ataur Rahman, M. Arifin, M. Mazian, Design and Development of A Scale Vertical Axis Wind Turbine for Electrical Power Generation, Journal of Urban and Environmental Engineering (JUEE), ISSN 1982-3932, volume: 1 Issue:2, 53-60, 2007.
5. M. Abid, K. S. Karimov, H. A. Wajid, F. Farooq, H. Ahmed, O. H. Khan, Design, Development and Testing of a Combined Savonius and Darrieus Vertical Axis Wind Turbine, Iranica Journal of Energy and Environment, ISSN: 2079-2115, volume: 6, Issue:1, 1-4, 2015.
6. ParthRathod, KapilKhatik, KetulShah , Het Desai , Jay Shah, A Review on Combined Vertical Axis Wind Turbine, International Journal of Innovative Research in Science, Engineering and Technology, ISSN: 2347 6710, volume: 5, Issue:4, 5748-5754, 2016.
7. B.O.Omijeh, C. S. Nmom, E. Nlewem, Modeling of a Vertical Axis Wind Turbine with Permanent Magnet Synchronous Generator for Nigeria, International Journal of Engineering and Technology, ISSN: 2049 3444, volume: 3. Issue: 2, 212-220, 2013.
8. KunduruAkhil Reddy, KalyanDagamoori, ArimalaParamasivamSruthi, SaiApurva.N,Nimmala Naga Maha Lakshmi Naidu, A.Vamsi Krishna Reddy, Beri Rajesh, KudaKiran Kumar, ChithaluriShivasri, SumamaYaqub Ali, A Brief Research, Study, Design and Analysis on Wind turbine, International journal of modern Engineering research (IJMER), ISSN: 2249–6645, volume: 5, Issue: 10, 5-30, 2015.