Comparative Study by modelling and simulating two types of Wind Turbines

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Introduction - Project Objectives

- VAWTs are more suited for installation at urban areas with slow and turbulent wind environments as these machines can start producing power at low speeds.
- VAWT have cost benefits as lesser blade material is used , lesser manufacturing costs , lesser installation costs (due to transportation) and lesser maintenance costs as drive trains are located at the base.
- After having understood some considerable advantages of VAWTs over HAWTs, we try to design and build two VAWT models- H Darrieus and Helix VAWTs.
- After building the required models, the models are simulated in stationary environments to check for various parameters such as pressure distribution across blades , shear stresses developed , etc.
- Finally assess financial viability between both of the models by comparing manufacturing costs.

Methodology

- Initially, we went through various research papers and then chose airfoil NACA 0018.
- Upon choosing NACA 0018, we chose the different parameters that we would build the model on.
- The H darrieus has one of the best performance among VAWTS and helix is an upcoming model, hence we wanted to compare them.
- Individual parts have been designed and assembled later to get final models.
- Several papers have been referred to decide on parameters required for simulations.
- Information regarding financial viability had been accumulated from different sources.

Validation

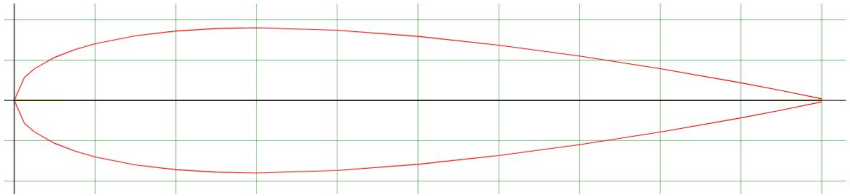
- Once the two models have been completed, we can compare them based on the common parameters.
- First we will analyze individually, and then we will proceed to compare them for different topological regions.
- We plan to minimize the errors in the comparison by mostly replicating the common parts like the Shaft, Stand, Connectors, etc.
- Also using the same airfoil type in order to obtain comparable results.

Modelling and Assembly of the VAWTs

Common Parameters between the 2 Models:

Airfoil Type: NACA 0018
Chord Length = 0.1 m
Vertical Height of Blade = 0.48 m
Radius of Turbine = 0.12 m

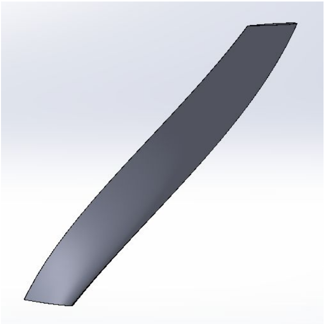
NACA 0018

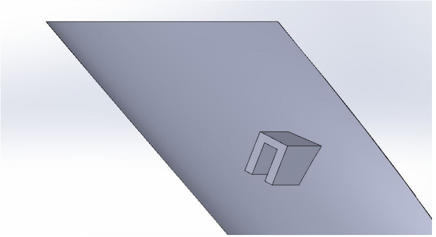


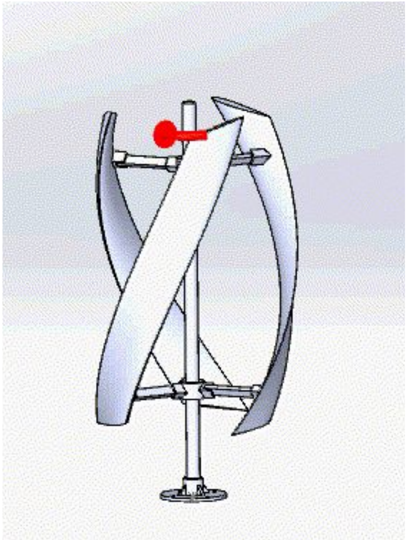
Helix Turbine

3 Rotor Helix Turbine
Angle Between Blades = 120 degrees
Diameter of Rotor = 0.24 m
Angle offset = 60 degrees

Surface Area= 8.99e-02 sq.m.





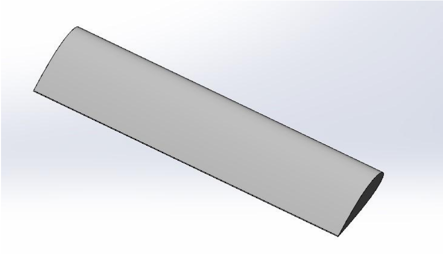


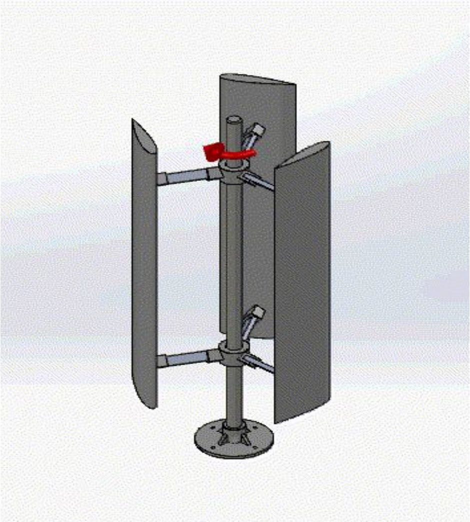
Modelling and Assembly of the Turbines

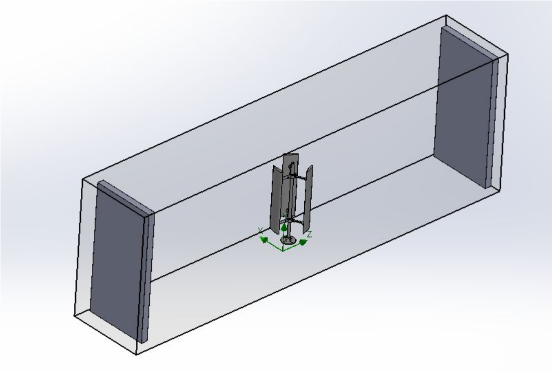
Darrieus-H Turbine

3 Rotor Darrieus-H Turbine
Angle Between Blades = 120 degrees
Diameter of Rotor = 0.24 m
Angle offset = 0 degrees

Surface Area= 1.06e-01 sq.m.



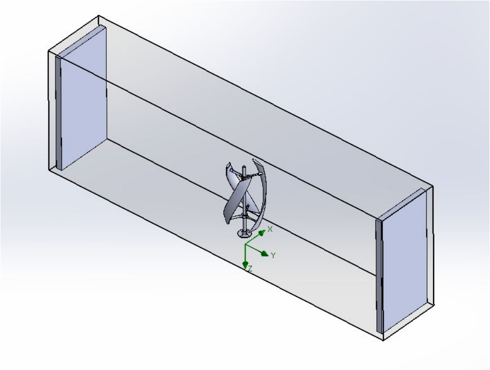




Wind Tunnel Walls

Length = 1m
Width 0.75 m
Distance from Turbine = 1.5 m

Symmetrically Aligned in Assembly



Simulations Methodology

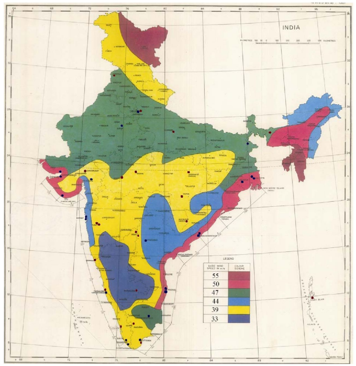
To study the performance of VAWTs at various regions and wind velocities we have referred to the Wind map of India, which depict the typical wind velocity in a region. We have selected three regions for the purpose of study where velocities are as

- 55m/s in most of the coastal regions, with RH as 60%.
- 47m/s covering northern half of the region with RH as 40%.
- 39 m/s extending to central and Southern India with RH as 50%.

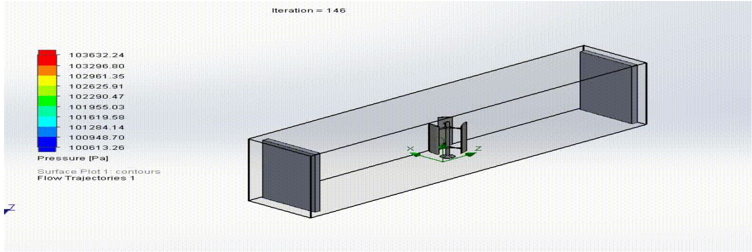
Simulations were carried out in Solidworks Flow Simulation with the type as External Analysis and using Air as the medium.

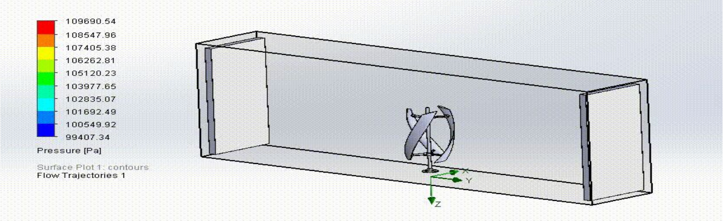
Computational domains have been set for both the walls.Boundary Conditions of Initial velocity and Atmospheric Pressure have been given on each wind tunnel wall.
Surface goals have been set to find out resultant parameters like forces, torques , stresses developed.

Parameters have been loaded and simulations have been run.
Then, visualizations using flow trajectories and surface plots have been obtained to interpret the results.



Parameter	Value
Parameter Definition	User Defined
Thermodynamic Parameters	
Parameters	Pressure, temperature
Pressure	101325 Pa
Pressure potential	☑
Refer to the origin	☐
Temperature	293.2 K
Velocity Parameters	
Parameter	Velocity
Velocity in X direction	0 m/s
Velocity in Y direction	0 m/s
Velocity in Z direction	0 m/s
Turbulence Parameters	
Parameters	Turbulence intensity and length
Turbulence intensity	2 %
Turbulence length	0.005 m

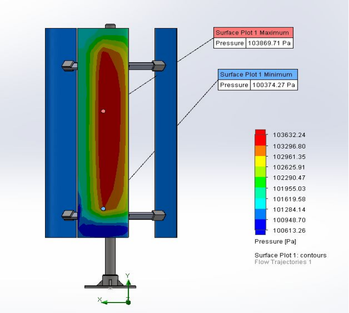


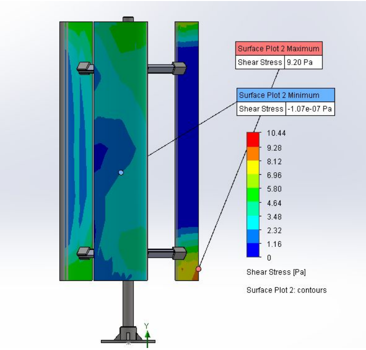


Inferences from Contour Plots-H-Darrieus VAWT

Region	H Darrieus	Helix
Coastal	103.8/100.3	102.1/100.5
Plateau	102.5/100.8	102.6/100.5
Northern Plane	103.2/100.6	101.7/100.9

Table-Pressure Drop across blades



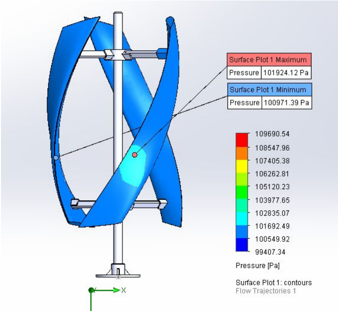


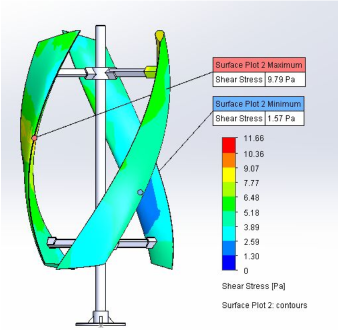
After comparing both models, pressure plots were obtained on the surfaces for all the blades and we observed that for H Darrieus Turbine there was a significant drop in pressure across turbine blades in all three regions compared to helical turbine.

For Helix Turbine, it is found that of lesser pressure drop and but larger difference for shear forces on the rotor blades.The opposite has can be observed for H Darrieus turbines.

Differences in shear stress near edges for H Darrieus is greater than for helical, which may lead to quicker blade erosion.

We found that a certain amount is turbulence built up around H Darrieus in the three regions studied. This cannot be seen in helical turbine, by which it can be said that Helical would more efficient for velocities that are spread throughout the the day





Financial Viability-VAWT Costs and Manufacturing

- The VAWT towers cost $ 11,000 (Rs. 8,25,798.60) to build. HAWT costs more than $22,000 (Rs. 16,51,597.20).
- VAWT blades can be made in bulk using pultrusion or extrusion techniques of fiberglass or aluminum because the blades are equal in length. Hand-made HAWT blades are therefore more expensive than those made in a factory.
- VAWT installation does not require long, expensive cranes which are required for HAWTs, and does not require highly skilled personnel
- The acquisition cost of the site and the stage cost of the HAWT project are between 3% of the total cost, and will not be required for VAWT projects under assets as this infrastructure is already funded for the construction of the first wind farm. 2% of site building costs may be incurred at approximately $ 40 / kW for adding DT Bird units to similar VAWT arrays. With evidence that this technology keeps VAWTs from harming birds, the cost of allowing understory should not increase the cost of project development
- A MW of VAWTs (14.3 electric generators using CVE will generate approximately 3,250,000 kWh per year at a 7.5m / s wind source. At a conversion rate of 1.22 lbs. CO_2 per kWh of gas-generated natural gas-powered wind power that could replace CA, it could take up to 0.57 years to extract the total amount of CO_2 produced from VAWT

Comparisons

H Darrieus Costs and Manufacturing

- The turbines are Darrieus-type VAWTs with rotor diameters of 17 metres and heights of 25.15 metres . They can generate 100 kW of electricity at a very reasonable cost (at 3 cents per kWh) in an 18 mph prevailing wind with annualised expenses of 12%.

Model	Volume (cubic mm)
H Darrieus	5.89e+05
Helix	4.98e+05

Helix Wind Turbines Cost and Manufacturing

- Currently, Helix is reviewing the UL and CUL listing to qualify for discounts under the aegis of state renewable energy programs. The base price of Helix is $ 6,500 (Rs. 4,88,325.18) before the tower and installation. The lowest model starts at $ 8,500 (Rs. 6,38,579.08) and the larger 5kW model starts at $ 16,500 (Rs. 12,39,594.68).
- Helix Wind is a standard 2kW turbine that can be fitted inside a tower between 14 and 35 metres tall or on a roof less than 2 metres above the ground. The Rotor quantifies 6ft by 4ft (1.8m by 1.2m) and employs numerous helical blade scoops to boost energy efficiency in turbulent, dynamic, or interdisciplinary climatic conditions.

Conclusions

- The Darrieus-H turbines' simple and convenient development and manufacturing results in an easy construction as well as an ease of installation of the turbine. In contrast to the Helix turbine, these attributes result in significantly lower costs.
- The Helix model is not harmful to the environment. The rotor rotates more slowly than horizontal turbines, and both birds and bats perceive it as a solid surface. Bird-blade accidents are particularly upsetting in "big" turbines, but the fact that the Helix rotor does not confuse birds is an added benefit.
- The ability of the rotor to spin in just about any airflow conditions makes it ideal for urban locations. The Helix turbine's low altitude and quiet operation make it a neighbourhood and zoning committee friendly. In terms of sound, Helix operates at less than 5 decibels above background noise.
- From simulations, it can be said that Helix has greater life span than H-Darrieus because blade erosion greater in H -Darrieus because erosion is greater.
- Further advancements in this project can be to use this data to integrate Machine Learning Models to conduct Conditional Monitoring for the turbines which will drastically reduce the operation and maintenance cost.