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FINITE ELEMENT ANALYSIS OF UP-WIND AND DOWN-WIND COMBINED HYBRID HORIZONTAL AXIS WIND TURBINE (HAWT)

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ABSTRACT: *Renewable energy is prime importance now a day because consumable fuels are reduces & their prices are increases. In case of wind energy upwind HAWT having success because of its high power generating capacity but having disadvantage of not utilizing wind energy available at the back side of the structure so in order to optimize power output from same HAWT structure this study is carried out. In which upwind & downwind turbines are attached in a single structure & power output is analyze by using different geometry of wind blade.*

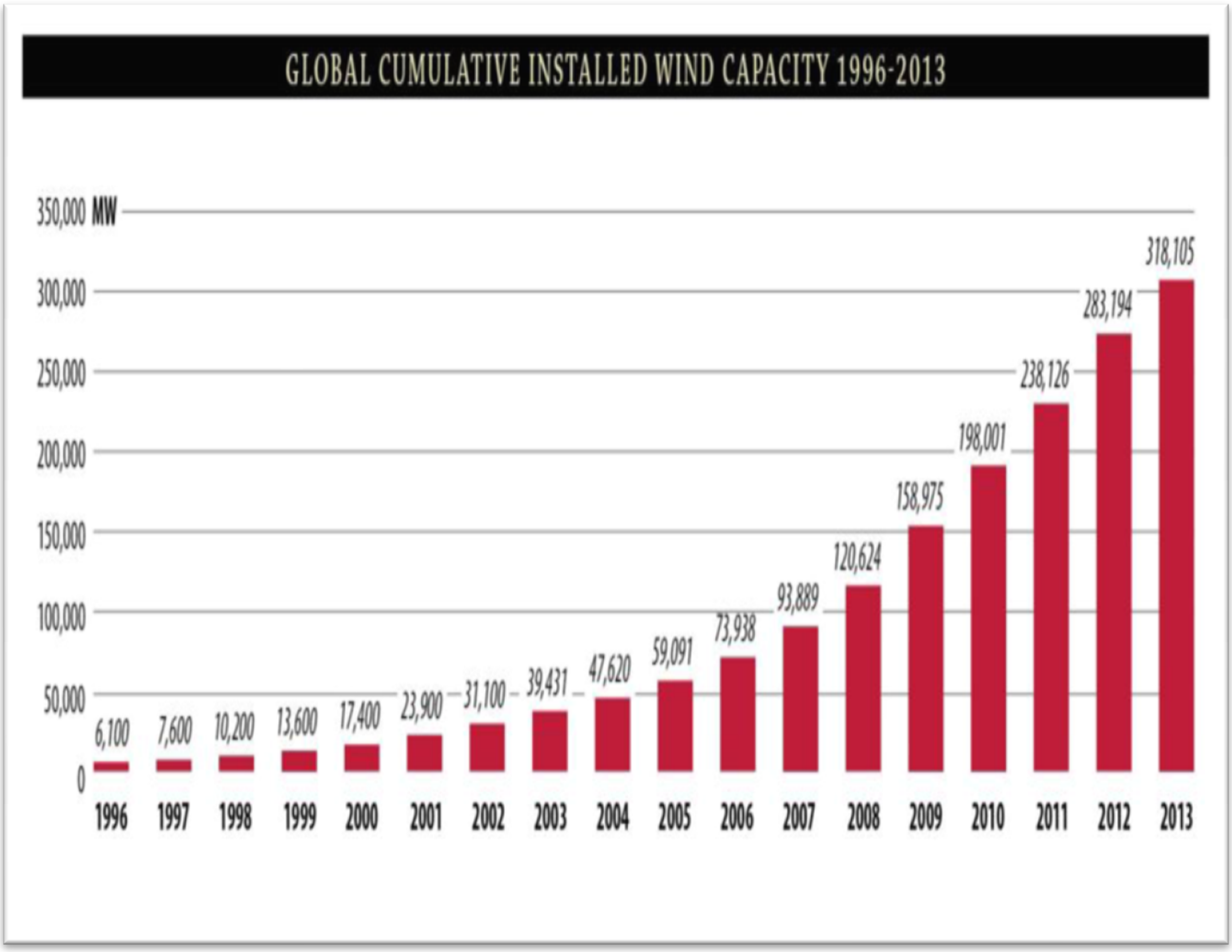
INTRODUCTION

An ever cumulative energy crisis happening in the world it will be important to examine alternative methods of producing power in ways different than fossil fuels. In fact one of the biggest sources of energy is all around us all of the time the wind.

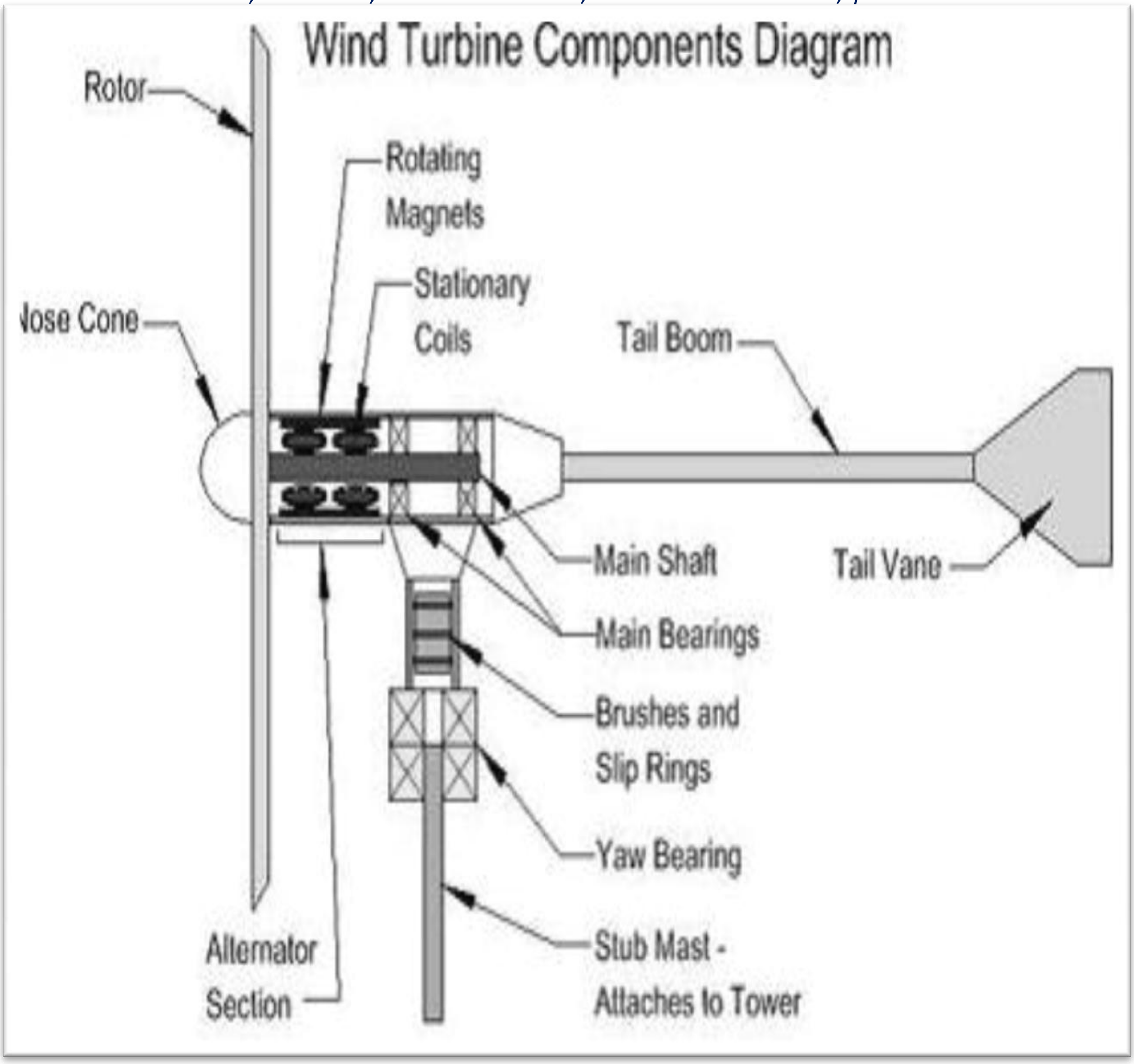
India was amongst the first countries in the world to set up a ministry of new and renewable energy resources (MNRE), in early 1980s. Thus all of India's renewable energy projects and their scope come under the MNRE. Today, the net grid tied renewable energy capacity has reached 29.9 GW of which wind energy contributes for 67% , while solar PV contributes nearly 4.59% of the renewable energy installed capacity in India. Hence, clearly wind energy has the highest scope of all renewable resources in India.

Wind is an abundant energy resource ultimately powered by the Sun. It is projected that about 3% of the Sun's thermal energy is transformed into wind energy. Wind is a vast energy resource which is clean and renewable. By its intrinsic nature, wind power has the potential to decrease the environmental impact on wildlife and human health. Improvements in power electronics, materials, and wind turbine designs allow production to continually lower the cost of wind generated electricity making it today economically viable compared with most other fossil fuels. Here statistics of power generation using wind energy all over the world is shown in figure during 1996-2013.

Wind turbines are devices that convert mechanical energy to electrical energy. Until the World War II their use was limited to Denmark, but later they have been gained popularity to utilize wind energy as a renewable resource.Wind turbines are classified into two main groups as *Horizontal (HAWT) and Vertical (VAWT) axis wind turbines.* This classification is done according to the axis of rotation with respect to the air flow direction. As seen in figure for HAWTs the axis of rotation is parallel to the air flow, while it is perpendicular VAWTs.



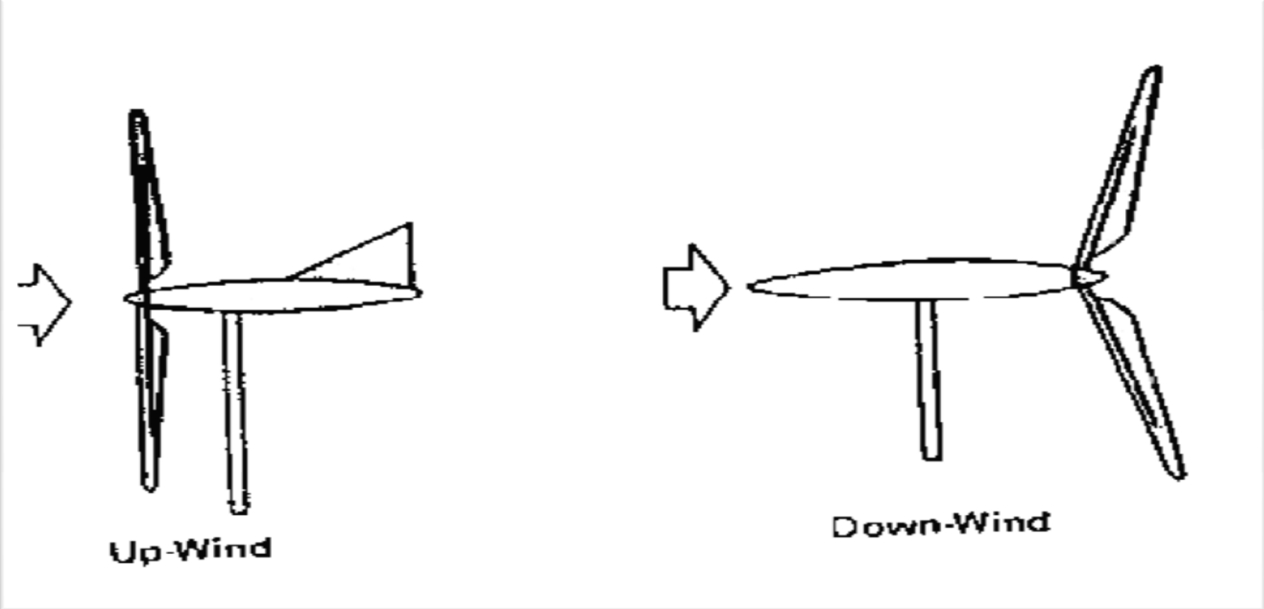
The most important difference between these two types is the dependency to the wind direction. VAWTs always rotate perpendicular to the wind, wherever it is coming from, i.e. their operation is independent of the wind direction, which is an important advantage. On the other hand wind direction is crucial for the effective operation of HAWTs.



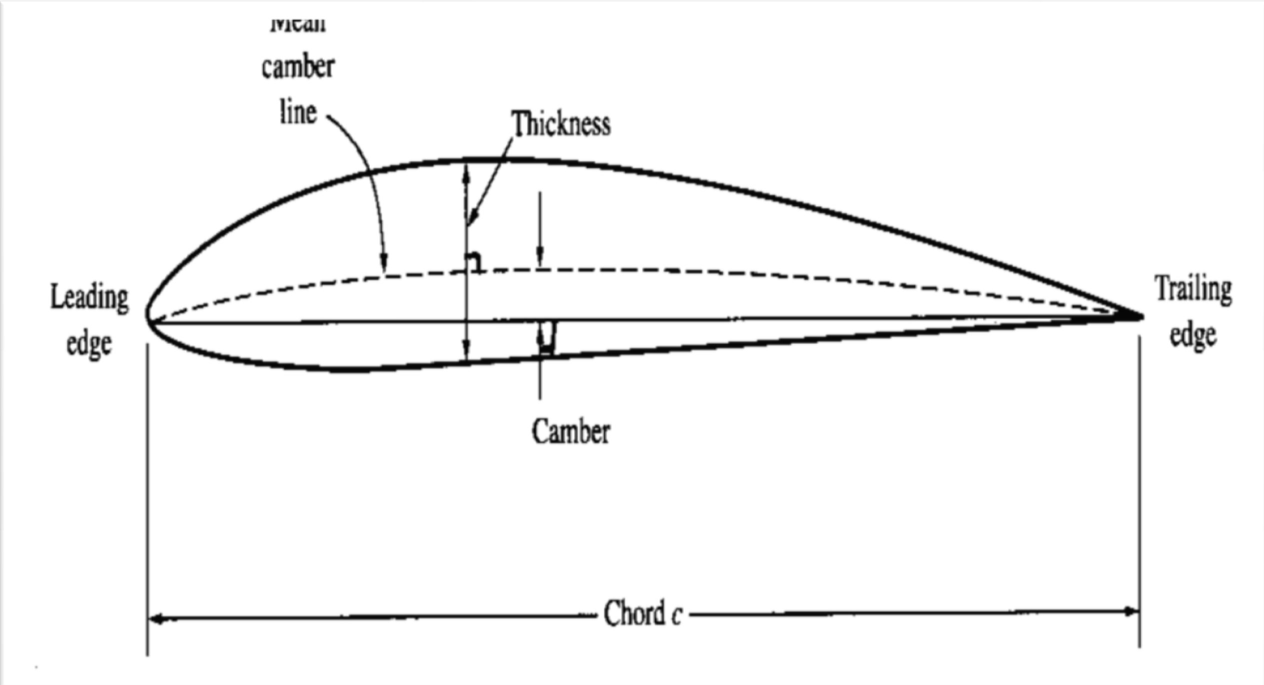
CONCEPT OF UPWIND AND DOWN-WIND TURBINE

The wind turbines which face wind stream from front side are called upWind turbine.

The wind turbine which receives wind stream from the rear side is called down wind turbine.



Airfoil Nomenclature



LITERATURE REVIEW

Prof. Ankit P. Ahuja [1]Based on the CFD analysis of the flow over NACA 0012 air foil we can conclude that at the 0 degree of AOA there is no lift force generated and if we want to increase amount of lift force and value of lift coefficient then we have to enlarge the value of AOA. By doing that obviously amount of drag force and value of drag coefficient also increased but the amount of increment in drag force and drag coefficient is quite lower compare to lift force.

Variables	0 degree of AOA	6 degree of AOA
Drag force	21.79 N	40.0502 N
Lift force	0.2487 N	888.7298 N
Drag coefficient	0.01373	0.02566
Lift coefficient	0.00015	0.56947

Jon De Coste [2] Design Project Vertical Axis Wind Turbine made model of SB-VAWT using NACA0012 profile evaluate the performance of it. It was found that VAWT performs well at certain TSR. At starting it faces negative torque which is referred as "dead band" in which little or negative torque make unable to start turbine as low TSR. So, it considers as major drawback of VAWT.

Rahman H Hetal[3] in this paper detailed analysis is complete for symmetric NACA airfoils that are usually referenced in the literature with 12%, 15% and 18% thickness by using CFD simulation. The results are presented for TSR range from 1.0 to 4.0 and for a range of oncoming wind SPEED from 6 m/sec to 14 m/sec. The NACA0022 gives the best overall performance. Although the NACA0012 gives a good performance at higher rotational speeds or tip speed ratio, it performance at lower rotational speeds is moderately low. NACA0015 gives the steady performance. NACA0012 and NACA0015 gives better performance at TSR=4.

Prof. Bharat Gupta [4]in this paper a horizontal axis wind turbine blade with NACA 4420 is designed and analyzed for different blade angle and wind speed. It could be observed that the upper surface on the airfoil experiences a higher velocity than the lower surface. By increasing the velocity at higher mach numbers there would be a shock wave on the upper surface that could cause discontinuity.

Sr. No	Blade Angle °	Velocity (m/s)	Density (kg/m^3)	Power (W)
1	0	15.5	1.225	1457710.87
2	22.5	16	1.225	1603379.2
3	37.5	16.05	1.225	1618457.90
4	45	16.10	1.225	1633630.84
5	60	16.17	1.225	1655031.85
6	75	16.94	1.225	1902902.40
7	90	17.8	1.225	2207680.92

Edoardo Frau [5] this research paper is based on benefits and drawbacks of downwind compared to upwind wind turbines. The configurations are based on a commercial, multimegawatt, three-bladed horizontal axis wind turbine. For the same operating conditions, the results of the simulations show that the downwind configuration has a 3% higher power output in comparison to the upwind configuration. This higher power is a consequence of several factors including higher flow incidence across the blade span and a higher axial velocity over the inboard portion of the blade span. The higher output power of the downwind configuration compared to the upwind configuration is also accompanied by a 3% higher thrust and factor 3 larger peak-to-peak variations of the unsteady loads.

In addition to the aforementioned flow features, these drawbacks arise due to the 14% higher loading on the blades of the downwind configuration, and more pronounced changes in flow incidence during the blades' rotation. Specifically, there is a 2 deg and 3 deg change in flow incidence at blade spans of 30% and 75%, respectively, as the blades pass through the tower wake on the downwind turbine.

On the other hand, there are changes in flow incidences of 0.3 deg and 1.0 deg, respectively, for the upwind configuration. As the downwind configuration is better suited for the use of more flexible blades, the assessment of this work provides a framework for the design of multimegawatt downwind turbines for the rapidly growing offshore wind market.

Shigeo Yoshida [6]I can conclude from this paper that to prevent blades touching towers, upwind turbines have their rotors tilted positively, and downwind turbines have negative rotor tilts. Consequently, there is an energy generating advantage for downwind turbines in up-flow wind. A test site was chosen where the wind had a natural up-flow of between +1 and +11 deg. Field tests in both upwind and downwind configurations, demonstrated that the downwind configuration generated between +5 and +20% more electricity than the upwind configuration. The rotor tilts angle was–6 deg for the downwind configuration and +6 deg for the upwind configuration. Local area wind simulation, at likely turbine sites in a typical complex terrain, showed that the wind vector is distributed mainly with positive inclination. Similarly dimensioned turbines in the simulation case study, the simulated downwind turbines generated 7.6% more annual power than the simulated upwind turbines.

Taeseong Kim [7]In this paper, three different turbines have been compared in order to examine the potential for an extreme load reduction with partial pitched blades and to compare principal difference between 2- and 3-bladed turbine dynamics with a rigid hub. The most dominating difference is the load transfer from the rotor to the tower where 2P and superior harmonic frequencies are excited in the tower by the 2-bladed turbine, while a multiple of 3P excitation occurs in the three-bladed turbine. A new and interesting finding is that the wave and boundary related frequencies of 2-bladed turbine were spread with ±1P frequency and multiple P frequency, whereas the frequencies are only spread with ±1P frequency for the three-bladed turbine. From the two-bladed turbine, it has been observed that the tower frequency is spread with ±2P frequency as well. For the two-bladed turbine, the tower bottom torsion is increasing more quickly compared with 3-bladed turbine when the yaw rate is raised.

Prof.S.Y.Kamdi [8] by this paper I can say thatPVC blade profile has better power capacity. Creates scopefor designing& Performance evaluation of a specially designed micro wind turbine for area especially in plateau region where velocity of wind is low, invariable average and dry, so where large wind turbine doesn't give satisfactory result. The small wind turbine i.e. multi blade turbine with increase in number of blades can be run successfully with proper adjustment of swept area and angle of attack. The benefit of the micro wind turbine is that, apart from its low cost, it can be propelled by a wind speed as low as 2 m/s.It is the renewable source of energy which is the dirt free source. It can be installed over the house for power generation in our local areas because of low cost and being of economical. Using of small wind turbines for house hold would plays a vital role in reducing utilization of conventional energy and mobility to utilize the power.

Norzelawati Asmuin [9] by reading this paper I can conclude that both types of turbines, whether VAWTs or HAWTs, are used for generating electrical power from the wind. This work has compared both types, and also presented the advantages and disadvantages of both types. It depends on the wind velocity and put to be fixed on. Any way the horizontal axis with propeller blades is the most common one, since its efficiency is about 60%.

Dr. S Srinivasa Prasad [10] from this paper I can say that Fluid-structure interaction plays prominent roles in many ways in the engineering fields**.** The stresses induced corresponding to the flow has been successfully computed using the ANSYS Workbench.This project provides the complete exposure to the FSI problem and gives the complete study of fluid on structure and vice-versa

CONCLUSION

From all above research paper I can conclude that HAWT wind turbine has starting torque less as compared to VAWT.NACA 0012 profile is efficient than other type of profile, For the same operating conditions, the results of the simulations show that the downwind configuration has a 3% higher power output in comparison to the upwind configuration, General dynamics of wind turbines with 2 and 3 blades were compared. The most dominating difference is the load transfer from the rotor to the tower where 2P and higher harmonic frequencies are excited in the tower by the two-bladed turbine, while a multiple of 3P excitation occurs in the 3-bladed turbine. And finally I also says that CFD analysis can give best result to find power output.

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