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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

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.

Generally two tyoes of wind turbines are used, HAWT and VAWT (vertical axis wind turbine). But in VAWT there is self starting problem.

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.

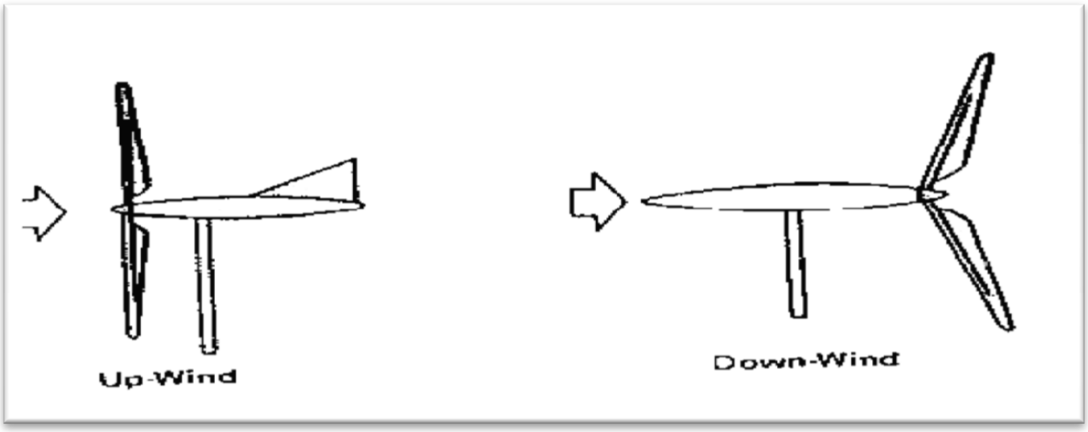

Fig 1 upwind & downwind turbine

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.

Table 1 angle of attack

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.If blade angle and velocity increase than power is also increase

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.

Prof.S.Y.Kamdi [7] 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.

Dr. S Srinivasa Prasad [8] 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

MODELING AND CFD SIMULATION

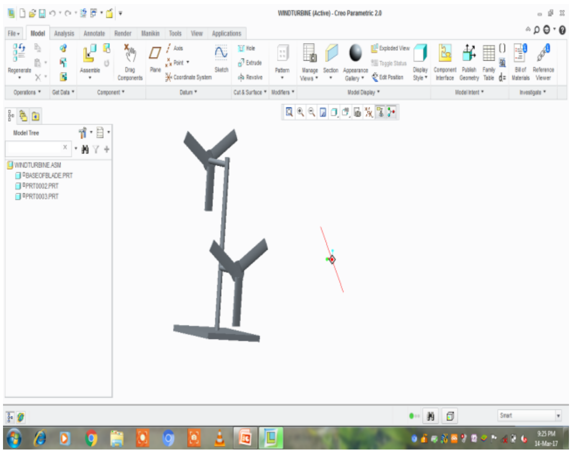

Fig 2 Creo modeling

Fig. 3 working model

Components and detail description of model:

1. **Shaft:** The mild steel shaft shaft with outer diameter 10 mm is used as central must.
2. **Blades:** Straight blades of NACA 0012 airfoil are prepared from PVC with 40.5 mm. Bolts are provided on both ends of blades for assemblage with main links.
3. **Ball bearing:** Four ball bearings with inner diameter of 46 mm are used for reduce friction between fixed frame and shaft. Bearings are fixed in flange for mounting on frame.
4. **Gear:** Gears are used to transmit the power from central shaft to DC generator. Two metallic spur gears are used to increase the direct available revolution of rotor.
5. **Base and tower :** Both are from PVC material with 5.5 outer diameter.
6. **DC generator:** DC generator is attached to rotor with help of gears. DC generator is used to measure available power on output shaft for calculation. For maintain constant speed on rotor load on generator is varied using variable resistance.
7. **P**-N junction diod
8. **Battery :** 12 volt DC supply

Now we check performance of all the blade profile in ANSYS. And then we choose best profile by ANSYS CFD Simulation result. From CFD analysis we can get Coefficient of lift C_L and Coefficient of drag C_D

Procedure :

Save the creo (any other drawing software) model in IGES or STP format

Import file to ANSYS Workbench

In fluent upload geometry

Prepare enclosure and do Boolean substract operation

Give name selection (Inlet velocity and Outlet Pressure)

MESH the file

In setup select k 2 epsilon model in viscous-laminar flow

Select Air as a material

Give inlet velocity as boundary condition

In monitors select lift and drag force direction

Start calculation and give no. iteration.

We can get drag force in direction of X axis and lift force in direction of Y axis

Here I show images of NACA 0012 profile CFD simulation figure. Same way u can check all other types of blade profile.

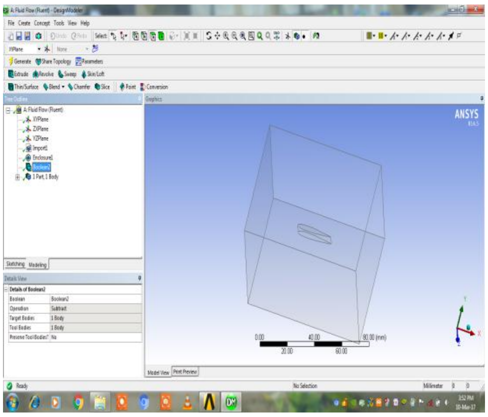

Fig. 4 Geometry

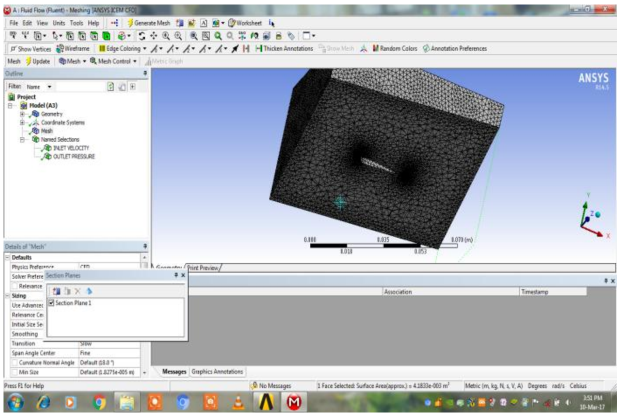

Fig. 4 Mesh

Taking initial velocity 10 m/s

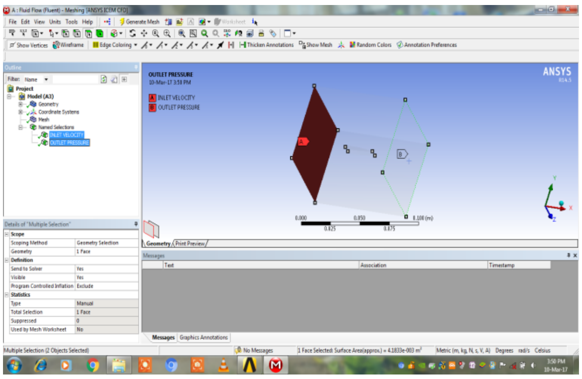

Fig. 5 Name selection

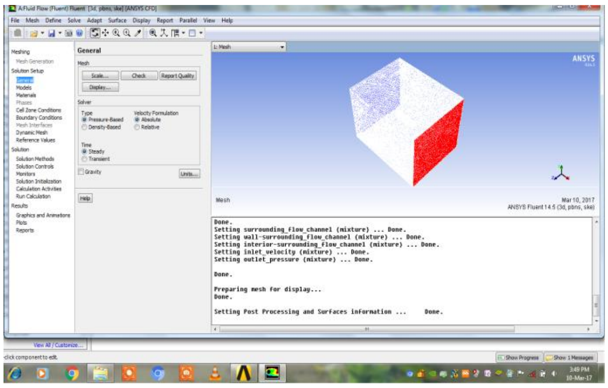

Fig. 6 Setup

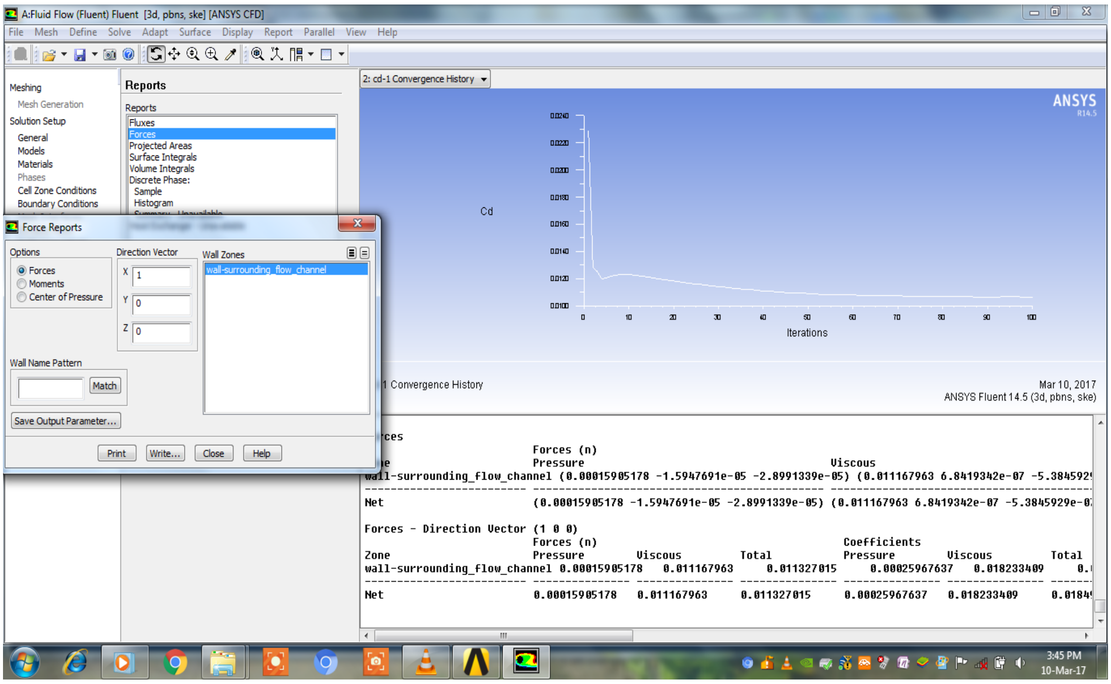

Fig. 7 Result

From above analysis F_L = 0.0000722 N & F_D = 0.00021 N

We can find C_L, C_D and power from following equation in following equation

$F_L=1/2(\rho AV^2 C_L)$

$F_D=1/2(\rho AV^2 C_D)$

$Ft=F_L\sin\varphi-F_D\cos\varphi$

$Fthrust=F_L\cos\varphi+F_D\sin\varphi$

P=(2ΠNT)/60 Where T=F*R[9]

Where φ is blade angle and R is radius of rotor

Now take density of air = 1.225 kg/m^3

Blade length = 0.0025 m

Wind velocity = 10 m/s

From above equation we can find C_L & C_D

Table 2 Result table

Blade Profile	1/2*Density*Area*V^2	F_L	F_D	C_L	C_D
NACA0012	0.001202031	0.0000722	0.00021	6.006499	17.47043
NACA0015	0.001202031	0.000000617	0.00022	0.05133	18.30235
NACA0018	0.001202031	0.0000345	0.000415	2.870142	34.52489
NACA0022	0.001202031	0.0000425	0.00043	3.535682	35.77278

From above observation table we can say that in NACA 0012 blade profile have high coefficient of lift than all other profile and low coefficient of drag. So from above equation in NACA 0012 profile have more power output

EXPERIMENTAL PROCEDURE

1. Wind turbine is started and wind velocity is measured anemometer.
2. Measured RPM of both upwind and downwind turbine with tachometer
3. Measured the voltage and current of both wind mill with multimeter
4. Check the current on series connection
5. Check the voltage on parallel connection.
6. Check the same performance on different altitude.
7. With use of the P-N junction diode I charge the battery

There are three measuring instrument are used in my project. (i) Anemometer for measurement of wind speed, (ii) Tachometer for measurement of RPM, (i) Multimeter for measurement of voltage, current

Table 3 ground level reading

GROUND LEVEL				
Position	**Voltage**	**Current**	**RPM**	**Wind Velocity**
Upwind	4 v	0.23 mA	103	4 m/s
Down Wind	2.10 v	0.19 mA	81	
Series Connection	NA	0.40 mA	-	
Parallel Connection	4.32v	NA	-	

Table 4 reading at height

On Height of 25 feet				
Position	**Voltage**	**Current**	**RPM**	**Wind Velocity**
Upwind	16.75 V	12.5 mA	300	9.5 m/s
Down Wind	12 V	8.9 mA	265	
Series Connection	NA	20 mA	-	
Parallel Connection	14 V	NA	-	

In my experiment I used 13.8 V DC battery and 12 V LED light .In above circuit diode is used because of the prevention of reverse flow. Main function of diode is to prevent reverse flow from battery.

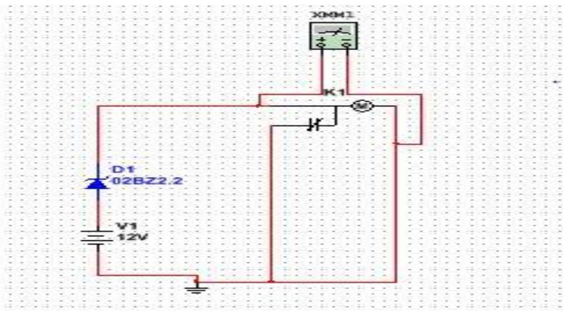

Fig. 8 battery charging with individual turbine

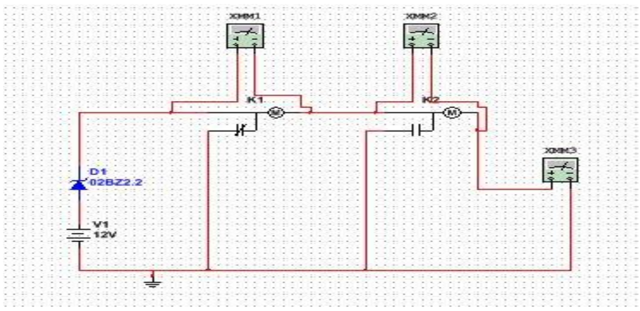

Fig. 9 Battery charging with series connection

If we charge our battery via series connection of both the turbine then we can reduce charging time because we know than in series connection current is being total.

Table 5 Battery reading

Position	Voltage before charging V_1	Voltage after charging V_2	Difference V_2-V_1	Time	Charging time
Upwind	10.49 V	13.5 V	3.01 V	5.20 min	23.8 min
Downwind	11.45 V	12.75 V	1.3 V	2.40 min	25.47 min
Series	11.95 V	12.8 V	1.85 V	3.25 min	22.48 min

CONCLUSION

The performance of HAWT is examined by practically as well as theoretically.

Major finding during complete dissertation works are summarize below :

(i) CFD simulation is more feasible tool for various analysis for more improvement of wind performance. Out of all blade profile NACA 0012 can give good performance.

(ii) We can utilize wind energy available at back side of HAWT structure

(iii) If we attaché combined upwind and downwind HAWT in same structure then we can get more power output than individual upwind or individual downwind.Only upwind can produce 16.75 V and only down wind can produce 12 V but if we combined than 28.75 V we can produce. So in combined arrangement we can produce 12 V more than upwind and 16.75 V more than down wind turbine.

(iv) In series connection of both the turbine we can reduce battery charging time than individual connection of both the turbine

From all above four points we can say that we can optimize power output if we attaché upwind and downwind turbine rotor in same tower.

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