Conceptual Model of Vertical Axis Wind Turbine and CFD analysis

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Abstract*— Fossil fuels are depleting at very fast rate and will have shortages in near future. Also prices of fuels increases day by day, demands for renewable energy sources increases for electrical power generation. Wind energy is available in nature in free of cost and in abundant form is excellent option for generation of electric power through wind turbine technology. Wind turbine is machine used to convert kinetic energy of wind to electrical energy. This paper explains basically the renewable energy status in India and scope of small scale vertical axis wind turbine for home application for power generation.

***Keywords*— wind energy, vertical axis wind turbine, horizontal axis wind turbine, renewable energy.**

I. INTRODUCTION

The non-renewable energy sources are broadly classified in to two main categories which are Oil and coal. Since these are non- renewable sources and extensively used for generation of electricity and in automobile industry. These resources are limited and hence will get exhausted in near future. The wind is available abundantly as natural resource. We know that there is sufficient wind available globally to satisfy much, or even more, of humanity's energy requirements, if it could be harvested effectively and on large enough scale.[1]

In the past the wind power was used for corn gridding, water pumping and for propelling ships for many centuries. Denmark was the first country to use the wind for generation of electricity from wind turbine of a 23 m diameter in year 1890. In year 1925, commercial wind turbine electric plants using two and three blades propellers was used for the first time. Most wind turbines designed with a two or three propeller blades rotating about a horizontal axis. These blades tend to be expensive. The difficulties in transporting, mounting the blades in wind direction made scientist to design and develop a wind turbine in vertical axis direction. Such attempt was made by National Research Coouncil of Canada in 1970's.[2] [7]

II. POTENTIAL OF WIND ENERGY IN INDIA

a) Energy Status In India

Recent Study In September 2013 by India Expo Center, Greater Noida shows that 87.7 % of the total energy used in India is non- renewable energy. The remaining 12.3% energy is shared by renewable energy.The details of share of % utilisation of energy in India is given in Table 1[6]

Table 1:- Breakup of energy for India

Sr. No.	Energy Sources	Type of energy sources	% of utilization of energy
1	Renewable Energy	a) Renewable Energy	12.3
2	Non- Renewable Energy	a) Coal Energy	58.4
		b) Nuclear Energy	2.1
		c) Gas Energy	9.0
		d) Oil Energy	0.5
		e) Hydraulic Energy	17.7
		Total % of Utilization of Energy	100 %

Electrical energy generation from renewable sources is increased in India with the share of 7.8% in year 2008 to 12.3% in year 2013. India has about 28.1 GW of installed renewable energy capacity as of 31 March 2013. The % break-up installed capacity from renewable sources is given in Table 2 [6]

Table 2-Installed Capacity of Renewable Energy In India:-

Sr. No	Type of Renewable Energy	Installed Capacity (%)
1	Wind Energy	67.9
2	Hydraulic Energy	12.9
3	Biomass	12.8
4	Solar Energy	6.0
5	Others	0.3
	Total	**99.9**

It is clear from the table that awareness regarding use of wind energy is increasing day by day. As on date installed wind capacity in India stands as 5th largest wind energy producer after China, the US, Germany and Spian. A Lawrence Berkeley National Laboratory study estimates India's wind energy potential is between 2,000 GW and 3,000 GW. State-wise wind energy status is given below in Table 3.[6]

Table 3:-State-wise wind energy potential and installed capacity (MW) and potential in India:-

Sr.No.	State	Estimated Potential (MW)	Installed Capacity (MW)
1	Tamil Nadu	14,152	7,162
2	Gujarat	35,071	3,175
3	Maharashtra	5,961	3,022
4	Karnataka	13,593	2,135
5	Rajasthan	5,050	2,685
6	Madhya Pradesh	2,931	386
7	Andhra Pradesh	14,497	448
8	Kerala	837	5
9	Others	10,696	4
10	All India	1,02,788	19,052

b) Global Installed Capacity of Wind Energy (%):- Worlds wind energy installed capacity is as given in Table 4

Table 4:- Global Installed Capacity of Wind Energy (%)

Sr.No.	Name of Country	Installed Capacity (%)
1	India	6.5
2	Canada	2.2
3	UK	3.0
4	Italy	2.9
5	France	2.7
6	Spain	8.1
7	Germany	11.1
8	US	21.2
9	China	26.6
10	Rest of World	15.7

III. TYPES OF WIND TURBINE

Modern wind turbines are classified in to two major types; Horizontal Axis Wind Turbines (HAWTs) and Vertical axis wind turbines (VAWTs).

A) HORIZONTAL AXIS WIND TURBINES (HAWT)

Horizontal-axis wind turbines typically has two or three blades. These wind turbines are operated "upwind," with the blades facing into the wind. The HAWT has three blades that rotates on a horizontal axis as shown in Fig 1. Almost all commercial wind turbines are horizontal axis machines with rotors using 2 or 3 airfoil blades. The rotor blades are fixed to a hub attached to a main shaft, which turns a generator normally with transmission through a gearbox. [3]

B) VERTICAL AXIS WIND TURBINES (VAWTS)

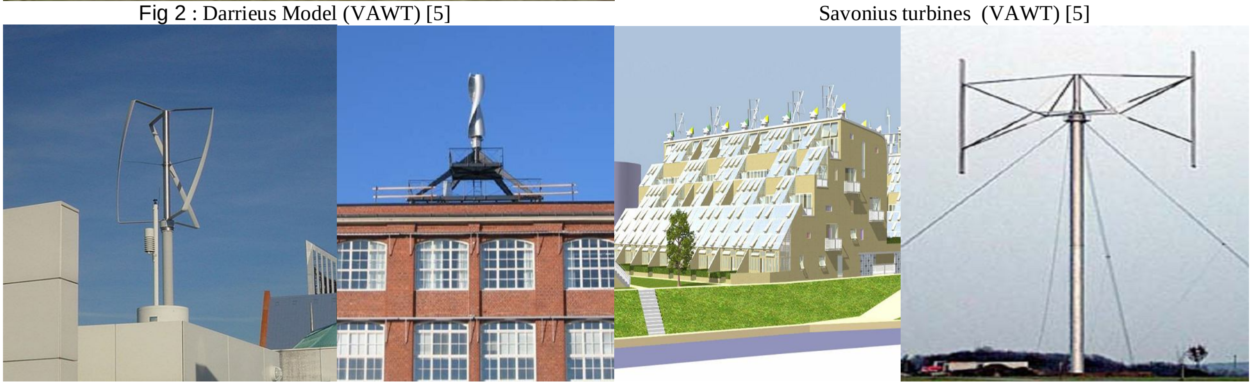
Vertical-axis wind turbines (VAWTs) are a type of wind turbine where the main rotor shaft is set vertically. Changes in wind direction have fewer negative effects on this type of turbine because it does not need to be positioned into the wind direction. Historically, VAWTs turbines are categorized as Darrieus and Savonius turbine, according to the principle used to capture the wind flow as shown in Figure 2.[8] Savonius turbines are one of the simplest turbines. Aerodynamically, they are drag-type devices, consisting of two or three scoops

Fig : 1 HAWT, Horizontal axis Wind Turbine [5]

Looking down on the rotor from above, a two-scoop machine would look like an "S" shape in cross section. Because of the curvature, the scoops experience less drag when moving against the wind than when moving with the wind. The differential drag causes the Savonius turbine to spin. Because they are drag-type devices, Savonius turbines extract much less of the wind's power than other similarly-sized lift-type turbines. Much of the swept area of a Savonius rotor may be near the ground, if it has a small mount without an extended post, making the overall energy extraction less effective due to the lower wind speeds found at lower heights. Figure 3 shows some models of VAWT viz Turby, WindSide , Urbun turbine and H type Giromills Turbine. All these models utilize the upward wind flows which are present around large buildings.[5]

Fig 2 : Darrieus Model (VAWT) [5]

Savonius turbines (VAWT) [5]



Turby *Wind Side* *Urban turbines* *H type Giromills Turbine*

Fig 3: Models of Vertical Axis Wind Turbine[5]

IV. WHY VERTICAL AXIS WIND TURBINE?

There are several reasons why we would choose a vertical axis wind turbine over a horizontal axis wind turbine. The main advantages of the vertical axis wind turbine over horizontal axis wind turbine are given below.[3]-[4]

a)VAWT can operate at low speed and start creating electricity and it can be built at location where tall building or structures are located. They are mounted near the roof which makes it easy for maintenance. It produces low noise during operation therefore suitable for living condition and hence recommended for home application.

b) VAWT rotates about a vertical axis and are always facing the wind therefore does not need to turned into the wind direction.

c) Safer operation and Spins at slower speed than horizontal turbines, decreasing the risk of injuring birds and simpler installation and maintenance. Besides the traditional installation site, it can be mounted directly on a rooftop. Can be installed in more locations like roofs, highways, in parking areas etc.

d) VAWT is inherently simple, less expensive to built and more aesthetically pleasant.

These inherent advantages make VAWT as growing field of research and development.

V. DESIGN OF VERTICAL AXIS WIND TURBINE

The proposed design of the vertical axis wind turbine model is shown in Fig.4. The overall dimensions of the model are diameter=1350mm, Height=900mm. This model is designed for radial entry trough out the length and axial exit from the top centre.

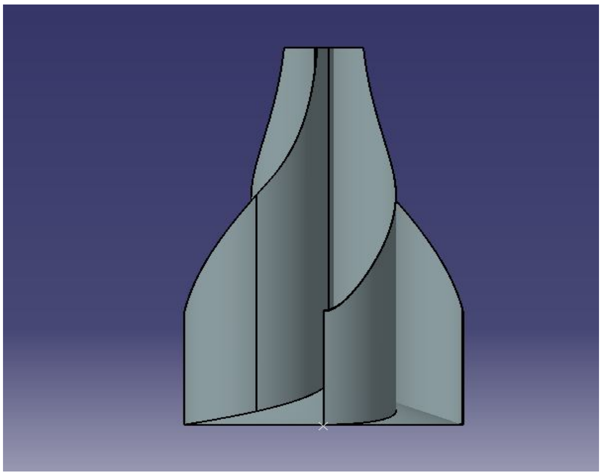


Fig.4 Vertical axis wind turbine

VI. OBJECTIVES OF THE DESIGN OF VAWT

1. New developed VAWT to be tested experimentally as well as on Computational Fluid Dynamics analysis (CFD) for validitation of electric power generation.
2. To make the appropriate torque measurement facility.
3. Electric power generation unit is to be connected to this turbine for power generation for house hold application.
4. Study of different parameters of vertical axis wind turbine viz., diameter of blade, blade design, blade width, blade angle for its performance.
5. To see the effect of mounting additional blade on vertical shaft.

VII. COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYSIS

The 3D model of VAWT blade is made in Catia/ Unigraphics with the given parameters. Turbine model meshed with 2D meshing with trigonal cells and 3D meshing with polyhedral and prism layer mesh close to blades of turbine. In this analysis, the wind turbine is tested in the wind tunnel and it is tested in two stages, one steady state for air flowing in the wind tunnel and after achieving the steady state, implicit unsteady state solution is done with dynamic fluid body interaction. The turbine is tested for air velocity of 6 m/s. Fig.5 shows the image of the wind is hitting on four blades. As it is clear from the image that the front two blades will experience the highest wind velocity. The bar shows the velocity values in full region of the image according to input air velocity that is creating the drag on blades and hence creating a couple to rotate the VAWT. As shown by the vector plots the wind is creating drag force in the blades and hence able to rotate the turbine Fig.6 shows the top view of VAWT with wind tunnel setup. The contour shows the wind profile after hitting on blades. Low pressure region is created on the right side of blades. The full model velocity profile is shown in the Fig.7. As the VAWT is creating obstruction in flow, the region behind the right side blades has low velocity. CFD analysis was done for the operation of turbine blade for 12 seconds. It shows that the turbine blade rotates at 130 rpm for model without gap between shaft and blades and it rotates at 50 rpm for model with gep between shaft and blades.

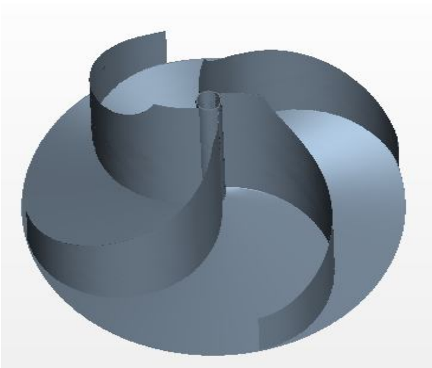


Fig.5: VAWT with no gap between shaft and blades.

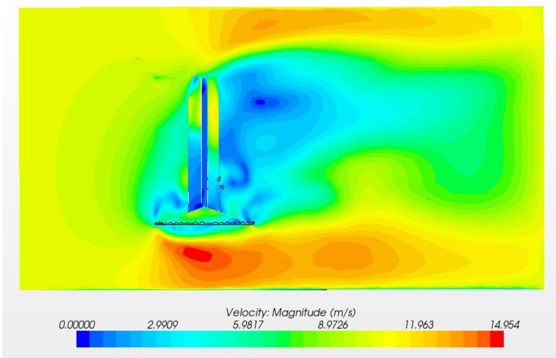


Fig.6: VAWT with wind flow.

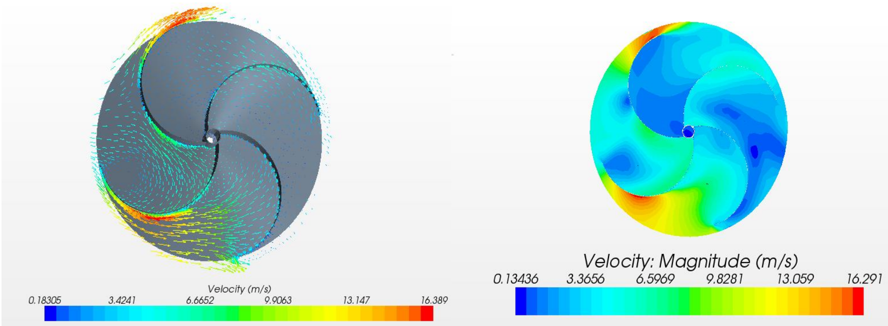


Fig.7 Top view of VAWT with wind tunnel setup

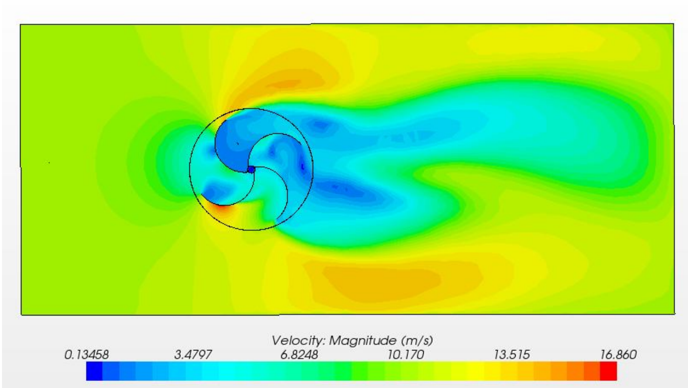


Fig.8: Velocity profile of VAWT

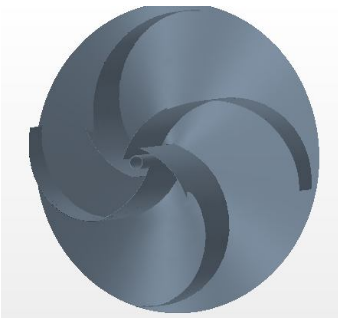


Fig.9 VAWT with gap between shaft and blades

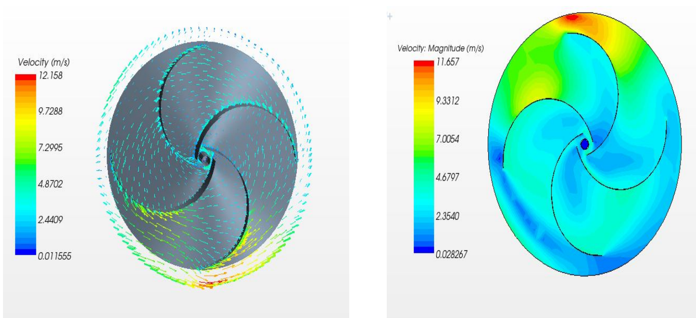


Fig.10 Top view of VAWT with wind tunnel setup

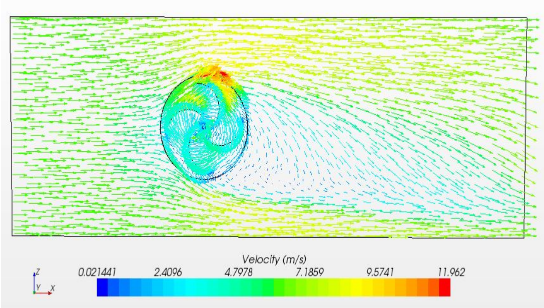


Fig.11: Velocity profile of VAWT

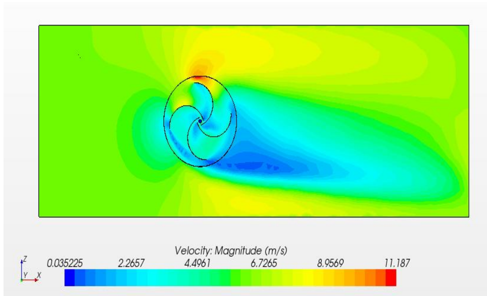


Fig.12: Velocity profile of VAW

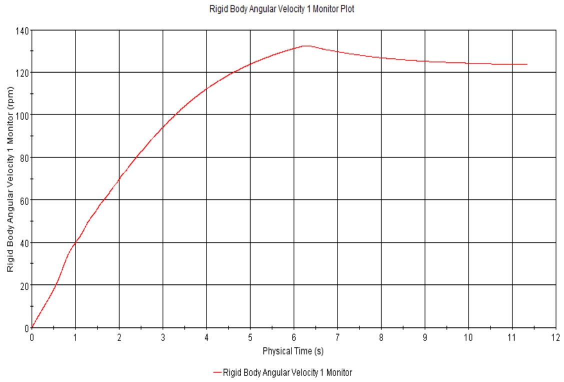


Fig.13 Rotation of VAWT without gap between shaft and blade

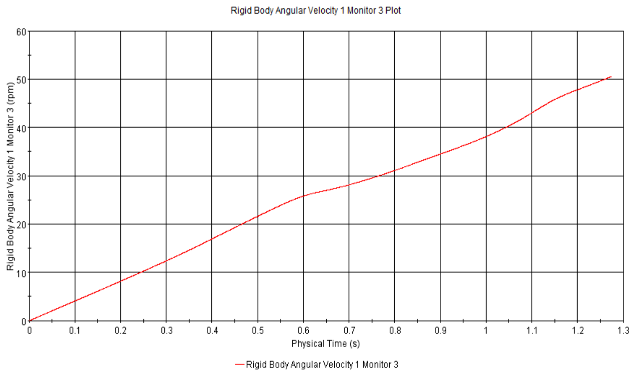


Fig.14 Rotation of VAWT with gap between shaft and blade

VIII. Conclusion

In this paper the blade was designed by using Catia software. CFD analysis was performed in order to obtain the velocity distribution of the air around the turbine blade and rotation of the blade in rpm for two model for further calculation of toque and power generation as output. From the CFD analysis, it is found that the turbine rotate at 130 rpm for 12 seconds for model without gap between the shaft and blades which is encourage result for further research study for experimental work and do the validation of the turbine by attaching appropriate torque measurement arrangement for power generation. The development of the vertical axis wind turbine in India has made significant progress during last 10 years. It appears to possess an inherent simplicity and many advantages that make it suitable for generation of electricity in large scale. Recently, due to incremental rate of environmental concern, wind energy development has experienced a significant of interest and considerable attention all over the world. Due to its simple construction and low maintenance cost, VAWTs can be effectively used for generation of electricity in India.

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