

# International Journal of Innovative Research in Science, Engineering and Technology

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## CFD Analysis of Savonius Wind Turbine with Guide Vanes

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**ABSTRACT:** This paper contains CFD analysis in the power development with the help of Savonius wind Turbine. As the express highway network is spreading all over country, on which heavy vehicles are running with high and controlled speed. So draft generated by the vehicles can be used to run wind turbine. This innovative method can generate clean energy from the wind turbine. As the availability of the wind from the vehicles will depends on traffic and atmospheric condition. Wind turbine will not solely depend on atmospheric wind; it can make use of HLV and natural wind energy resource. With positive move in this field of wind power generation, a unique power station is planned. Which will supply power to the near area and express highway. The analysis is done by using the Savonius rotor with two & three scoop of the rotor considering inlet guide vanes and the results are compared between with and without guide vane using CFD.

**KEYWORDS:**CFD, HLV, Vanes, Savonius.

### I. INTRODUCTION

CFD analysis is providing a very good approach in solving the flow over wind turbine. As the flow nature over wind turbine is complicated, CFD analysis provides a detail picture of the flow as experimental analysis of this complicated flow is too tedious. The development of wind power in India started in the 1990s and now the country stands fifth with largest wind power capacity in the world[1]. Big side to see that, day by day there is large increase in the consumption of the power. So, we require to meet the present and future requirement of the power, we have to extract or to develop large alternative sources for the power development. As there is development in express highway in each and every state of India, so we can make use of the space aside the road for the wind power station.

General, wind turbines are placed at suitable site in the open stream. In which number of wind turbine are install, with long blades having tall tower for holding. In this paper we have made the advantage of Heavy Locomotive Vehicle (HLV) which are running on the express highway with minimum speed of 100 Km/hr. To extract the maximum energy from the wind draft generated by the vehicle, we have tried to develop this by installing the stage Savonius Wind Turbine. As the turbine requires some directional flow, to avoid losses and extract maximum amount of energy from the wind, so we have provided guide vanes at inlet of the wind turbine. In these way CFD results of both with vanes and without vanes is compared.

### II. RELATED WORK

- 1) **FROHNERT, Alfred:** WIND FORCE PLANT, 03.12.1998: A wind force plant is equipped with a cone-shaped rotor, the tapered envelope of which is provided with several radially-projecting vanes distributed on its periphery, the ends of said vanes being covered by an external envelope. In this way, flow channels for the wind flow are provided on a section of the tapered envelope.
- 2) **Stimm, Kean W** wind turbine, September 2015: A wind turbine having a set of curved blades mounted on a central rotatable hub. Each of the blades has a defined pitch angle, to a rotational axis of the hub, along the

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blade from the hub to the tip. A curve is provided on the wind contact surface along each of the blades over the blade surface from the leading edge of the blade to the trailing edge of the blade by an amount between about 6 and about 24 degrees. The defined pitch angle from any point along the leading edge of the blade being defined by the arc-sine of a ratio of blade velocity to apparent wind velocity, with a variance of  $\pm 30$  percent of the complementary angle to the arc-sine; and apparatus for varying the velocity of the blade to control power output so that it is within fifteen percent of maximum obtainable power of the blade most distant from the hub.

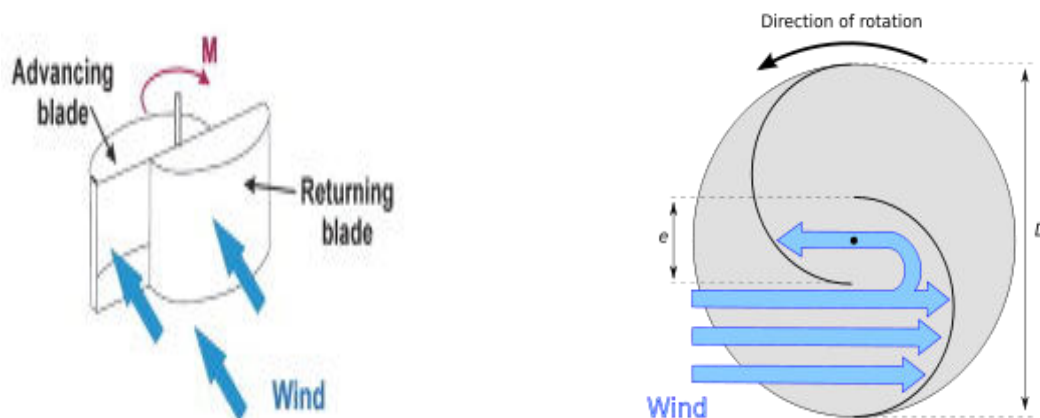
- 3) **Howard d. driver** (General Electric Company), Wind blade assembly and method for damping load or strain, Dec 2005: The transducers are incorporated in or laminated to wind blades and electrically connected to a self-powered electrical circuit. The transducers in combination with the self-powered electrical circuit improve the wind blades' response to changing wind conditions by reducing loads, at least until the turbines pitch axis system can alter the lie of the blades. Thus, when there is a change in wind conditions, the resultant twisting or bending of the wind blade during the impact of the wind (gust) on the wind blade is used to extract energy from the transducers. This energy is then transferred to the electrical circuit which in turn sends a signal back to the transducers to actuate them so as to resist the imposed load.

### III. CONCEPT OF WIND POWER STATION

As in our power station, we have selected Savonius Wind Turbine (SWT) In between and side of the road of Express highway. Concept for this type of power station can be summarized as follows.

### IV. SWT

Uses of SWT allow us to extract maximum energy from the air coming from the Vehicles. It has observed that aerodynamics of a savonius wind turbine is shown in Fig-1[3]



**Figure 1** Aerodynamics of Savonius Wind Turbine

As shown in figure it has capacity to capture wind in any direction. To avoid directional losses, we have provided guide vanes at inlet. SWT is constructed of two or more half cylinders as shown in Figure1. The ratio between rotor height and rotor diameter is aspect ratio. Performance of SWT is affected by overlap ratio  $\beta$  which is expressed as  $\beta = (e - a)/d$ , Where  $e$  is the overlap,  $a$  is the shaft diameter and  $d$  is the blade diameter. SWT are vertical-axis wind turbine (VAWT), used for converting the power of the wind into torque on a rotating shaft. SWT are one of the simplest turbines. Aerodynamically, they are drag-type device, consisting of two or three scoops. As per the setup top view of the rotor is a two scoop machined would look like an 'S' shape in cross section. As per the operation one of

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the scoop experience less drag when moving against the wind than when moving with the wind. The differential drag causes the Savonius turbine to spin. As SWT are drag-type devices, SWT extract much less of the wind power as compare to lift type of Turbines. Savonius turbines are used whenever cost or reliability is much more important than efficiency. Design is simplified because, unlike horizontal-axis turbines, no pointing mechanism is required to allow for shifting wind direction and the turbine is self-starting.

## V. EXPRESS HIGHWAYS FOR INSTALLATION OF WIND TURBINE

It has observed that wind speed rises proportionally to the seventh root of altitude. Doubling the altitude of a turbine, then, increases the expected wind speeds by 10% and the expected power by 34%[4]. Doubling the tower height generally requires doubling the diameter as well, increasing the amount of material by a factor of eight. At night time, or when the atmosphere becomes stable, wind speed close to the ground usually subsides whereas at turbine hub altitude it does not decrease that much or may even increase. As a result, the wind speed is higher and a turbine will produce more power than expected from the 1/7th power law: doubling the altitude may increase wind speed by 20% to 60. The origin of wind is complex. The Earth is unevenly heated by the sun resulting in the poles receiving less energy from the sun than the equator does. Also, the dry land heats up (and cools down) more quickly than the seas do. The differential heating drives a global atmospheric convection system reaching from the Earth's surface to the stratosphere which acts as a virtual ceiling. Most of the energy stored in these wind movements can be found at high altitudes where continuous wind speeds of over 160 km/h (100 mph) occur[5]. Eventually, the wind energy is converted through friction into diffuse heat throughout the Earth's surface and atmosphere. Looking into all above respect Wind turbines can be setup at express highway on road side where continuous wind draft generated by heavy vehicles at ground level is available along with natural wind. This type of setup can have all the advantages of saving in terms of cost for the installation and can get continuous flow of air. In one setup we can get maximum amount of energy.

## VI. DESIGN OF SWT

In the design of wind turbine, site location has to be selected on the basis of wind Energy availability. So survey data can give you the detail information regarding the wind energy. The express highway location will give the surface area for the installation of the plant. We can have the arrangement in between the lane and on the side of the express way.

Parameters for the wind power.

We calculate Wind Power ( $P_w$ ) as per the equation given below.

Wind Power ( $P_w$ )

The power carried by the wind is given by the equation;

$P_w = \text{volumetric flow rate} * \text{Kinetic energy per unit volume.}$

$$P_w = A * V \times \frac{\rho V^2}{2}$$

$$P_w = \frac{1}{2} \times \rho \times A \times V^3 \quad \dots \dots \dots (1)$$

where  $A = \frac{\pi}{4} \times D_r^2$

Power Generated by SWT.

Power generated by the wind turbine depends upon the number of stages, COP

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and wind power. COP depends upon the type of rotor and ratio of blade tip speed to the wind speed.

$$P_{tur} = COP \times P_w \times \text{number of stages} \dots \dots \dots (3)$$

## VII. ANALYSIS OF SWT

The location of the SWT should be aligned in the direction of the wind to get maximum efficiency. In india, normal direction of wind is south-west to north-east. So it should be in the direction of the wind stream. Their can be various paremeters for the analysis.

For our analysis there are some limitations regarding the height of the SWT and diameter of the turbine. Analysis has done with the two blade rotor.

Inlet Velocity  $V$  can be varied from 5 to 40 mph. (20 mph = 9 m/s)

- 1) Area (A) 0.333 m<sup>2</sup>.
- 2) Number of stages of turbine 1
- 3) we can take COP= 0.245 (24.5% from the standard Power Coeff. /Tip speed ratio diagram)

By considering all above parameters we can analysis the SWT

Sr. No.	Diameter (m)	Speed (N)rpm	Height (h) meters
1	0.4	477.5	0.83
2	0.5	382	0.67
3	0.6	318.3	0.56
4	0.7	272.2	0.48
5	0.8	238.8	0.42
6	0.9	212.2	0.37
7	1.0	191	0.330
8	1.1	173.6	0.303

Table 1- Height of rotor to diameter

The size of 0.83 X 0.4 is chosen considering the height benefit and maximum number of rpm. as in Table 1.

## VIII. CFD

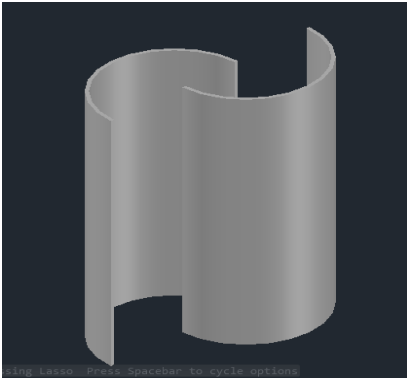
The CFD Analysis is carried out with set of savonius wind turbines with two number of blades with and without guide vanes. The wind turbines are implemented in a built environment by using CFD simulation in Ansys software, the pressures, the velocities and the turbulences are obtained. By using the results data from CFD simulations, the power coefficient, the acting torque, the drag forces and the generated power variation with the wind velocity determined. In order to achieve the CFD simulation, the geometrical model of the savonius wind turbines with 2 blades is made by using AutoCAD software as shown in figure:2.and with guide vanes as shown in figure:3.Earlier analysis is done without overlap of blades as shown in figure: 4.

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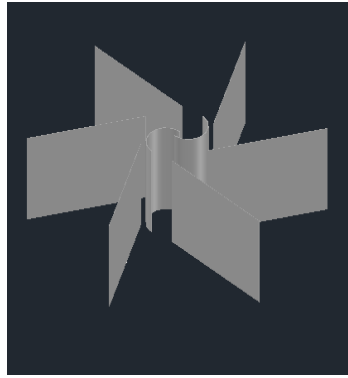
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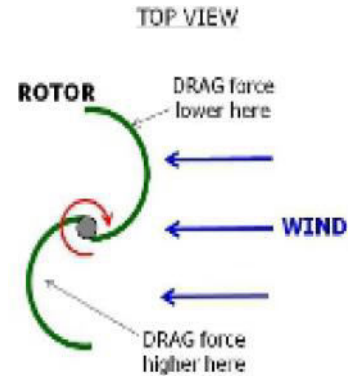
Vol. 7, Issue 4, April 2018



**Figure 2.** Model of Savonius Wind Turbine



**Figure 3** Model with Guide vanes



**Figure 4**

For all the savonius wind turbines is defined as a box type enclosure which represents the volume where the air will flow. The geometrical models are meshed in Ansys 16.2 software with a coarse smoothness and a fine transition of finite elements in the border areas; the span angle centre is imposed to be fine, also. After the analysis of the above wind turbines the best outcome was obtained from the 2 blades of turbine. The major drawbacks of the design are the drag forces on the return blade and produce the negative torque. So, the shaft is removed and plates are attached on top and bottom. The gap is provided between the blades so that the wind impacts on the opposite side of the incoming blades so that resultant force on the blade is reduced. The gap with ratio  $S/D= 0.1$  and  $S/D=0.2$  is provided. It is common practice to conduct aerodynamic performance tests for products like Savonius wind turbine inside wind tunnels. However, methods exist for purely numerical studies using computational Fluid Dynamics or simulator. They are sensitive to domain size, turbulence models used and the complexity developed by air flow. For the CFD analysis properties for air are Density of Fluid= $1.225 \text{ kg/m}^3$ , Fluid Viscosity= $1.789 \times 10^{-5} \text{ Ns/m}^2$ , Specific Heat=1.4, Reynolds Number=242247, Analysis Model= k-e.

Guide Vane is one of additional device that its function is for directing wind stream onto convex blade. That way it increased wind speeds to strike the rotor, consequently it produced higher coefficient thus Savonius rotor performed to get better performance. Here, circular geometry guide vanes are adopted instead of rectangular curtain arrangement deflectors. This straight Guide vanes consisting of 6 vanes. Free wind with velocity hits the guide Vanes and there will be increase in wind speed inside the Guide Vanes as a result of Venture effect created by it.

## IX. RESULTS & DISCUSSION

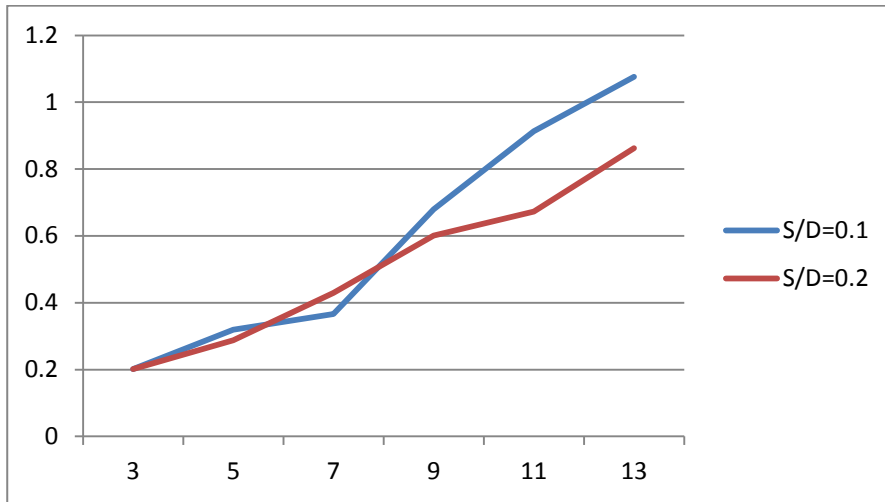
The numerical analysis of SWT shows tremendous rise in the power out of Wind Plant. As shown in Table:1 to get clear idea about the power develop by the SWT. From the below graph

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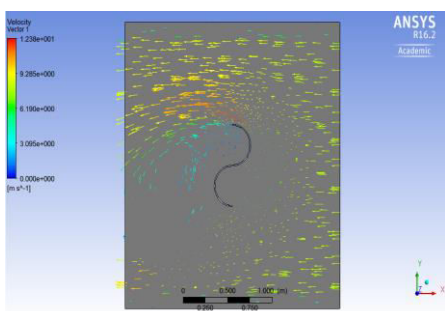
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Vol. 7, Issue 4, April 2018

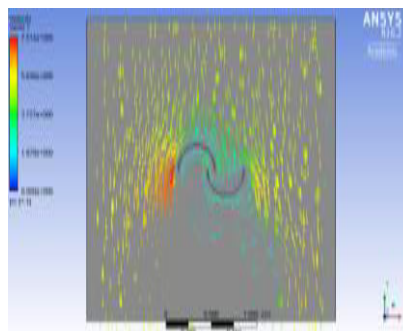


**Graph 1:** Graphical Representation of Speed vs. Torque

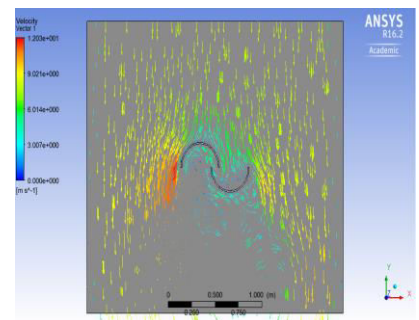
speed vs torque the blade having S/D ratio of 0.1 is selected. The energy left in the wind after colliding with the convex blade is used to decrease the drag force on the incoming blade concave blade. CFD results shown in Figure: 5, without overlap. Figure: 6, 7, & 8 shows the variation of two blades with overlap at 3,7 & 11 m/s Wind Speed respectively. and Figure: 8,9&10 shows with guide vanes at 3,7 & 11 m/s Wind Speed respectively. The CFD analysis carried out in ANSYS FLUENT 16.2 using steady state, k-e model.



**Figure 5** Wind Speed of 3m/s



**Figure 6** Wind Speed 3m/s



**Figure 7** Wind Speed 7m/s

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Vol. 7, Issue 4, April 2018

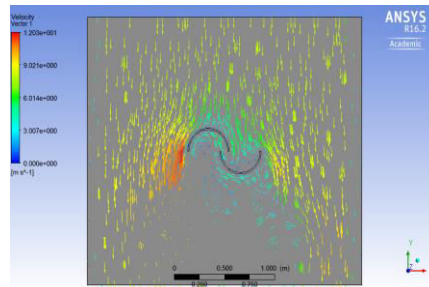


Figure 8 Wind Speed 11 m/s

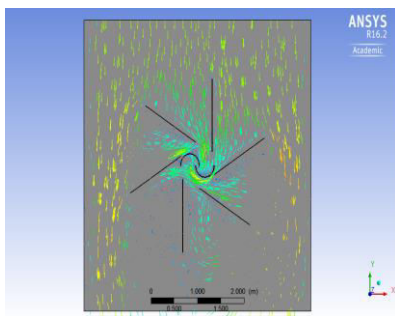


Figure 9 Wind Speed 3m/s

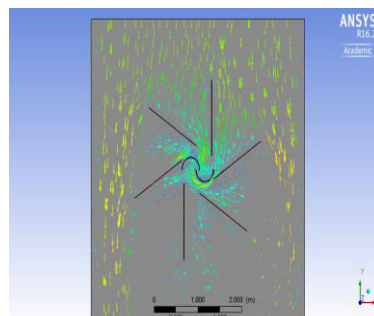


Figure 10 Wind Speed 3m/s

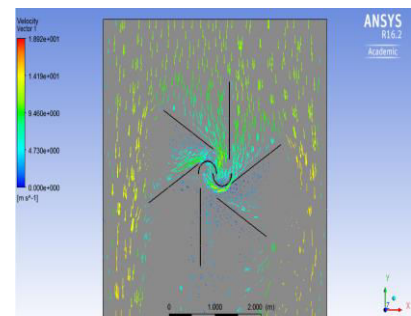
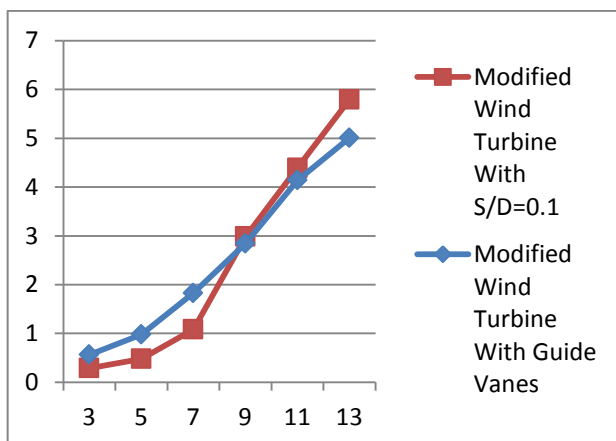
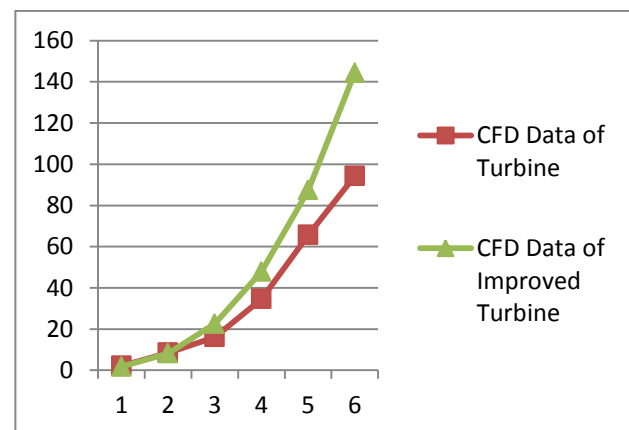


Figure 11 Wind Speed 3m/s

The graph 2, represents the variation of torque with different wind velocities. The torque increases with wind velocity. Graph 3 shows the rise in power for modified turbine. Because of the Guide Vanes that is not only helpful for the deflects the air at the mean time negative torque which is reduced and that craved venture-effect to increase the wind velocity these all improvement leads to increase the power development up to 8% as compared to that of without guide Vane savonius rotor. But as it can be noted from the graph that at high wind speed the guide vanes itself hinders in the rotation of the wind turbine. As the mass flow rate is high there is not enough space for the outlet of the air at high speeds. So, the air gets accumulated inside and pressure increases so the turbine blades are resisted in motion.



Graph 2 Wind Speed vs. Torque



Graph 3 Wind v/s Power

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Vol. 7, Issue 4, April 2018

## IX. CONCLUSION

The Savonius Wind turbine a class of vertical axis wind turbine can be viable option for small scale, low cost of grid energy conversion in certain cases of confined space and low wind speed region, where the other turbines cannot work efficiently. As per the results draft wind, with the various speed showing high potential for developing SWT for power generation. The present work shows Savonius wind turbine having enormous potential in extracting power at low wind speed. Two scoop type SWT shows good results. In this work importance given for negative torque on the advancing blade of the rotor. The CFD analysis carried out in ANSYS FLUENT 16.2 using steady state, k-e model. As per the result Savonius wind turbine negative torque that can be reduced by different types of guide vanes, which shows good results. Also, it is observed, increase in rotor power and power coefficient from the table 2.

Velocity	CFD Result of Turbine(W)	CFD result of Improved Turbine(W)
3	2.115	1.773
5	8.515	8.221
7	16.125	22.531
9	34.562	47.888
11	65.651	87.434
13	94.251	144.322

Table: 2

### Nomenclature:

A= swept area of the turbine, m<sup>2</sup>

COP= Coefficient of power.

D= Diameter of turbine, m.

P<sub>w</sub>= wind Power, watt.

V= Free air Velocity at inlet m/s.

$\rho$  = Density of air, Kg/m<sup>3</sup>.

e, S = overlap

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