

# Analysis of wind Turbine running on Draft generated by Heavy Locomotive Vehicle.

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**Abstract :** *This paper contains augmentation in the power development with the help of wind draft generated by Heavy Locomotive Vehicle(HLV). 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. The development of wind power has significantly increased in India. Many industries have led India to become the largest installed wind power capacity in the world. 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 and the results are compared between experimental and CFD.*

**IndexTerms -** HLV, Savonius, traffic, Express highway.

## 1. INTRODUCTION

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. Many private company has made India the developing country in advance wind turbine technology. MNRE has also fixed the target 6,000MW, might be available for commercial use by 2012[1] and 8800MW by 2017. 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. 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 turbine 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. In these way results of the experiment and CFD is compared.

## 2. 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.

### 2.1 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[2]Fig.2[3] & Fig3. As shown in figure it has capacity to capture wind in any direction. 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 as shown in figure:3.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 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.

### 2.2 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.

3.0 DESIGN OF HAMWT.

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.

3.1 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;

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

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

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

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

3.2 Power Generated by SWT.

Power generated by the wind turbine depends upon the number of stages, COP and wind power. COP depends upon the type of rotor and ratio of blade tip speed to the wind speed.

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

4.0 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 parameters for the analysis.

4.1 Parameters for the analysis.

For our analysis there are some limitations regarding the height of the SWT and diameter of the turbine. Experiment has done with the two and three blade rotor for the down stream conditions of the 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.

4.2 Experiment set up.

After theoretical calculation experimental setup is done for analysis considering the following condition.

- Rigid base – Mild steel Inner
- Fixed shaft- Mild steel (id=40mm, OD=50mm)
- Outer rotary hollow shaft- Mild steel (id=80, OD=86)
- Middle rotating disk- Mild steel 2
- Ball Bearing- Angular contact ball bearing(bore=80 mm)
- Rotor blade- Aluminium 7020 alloy (No. of blade=2 & 3)
- Tachometer for rpm measurement and anemometer for speed of wind measurement.

4.3 CFD analysis.

The CFD Analysis is carried out with set of savonius wind turbines with different number of blades and as per the experimental dimensions. 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 2-5 blades is made by using AutoCAD software as shown in figure: 4,5 & 6. 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 as shown in figure:6. 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.

## 5.0 RESULTS & DISCUSSION.

The numerical analysis of SWT shows tremendous rise in the power out of Wind Plant. Experiment result shown in Table:2 to get clear idea about the power develop by the SWT. From the figure:7 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: 8,9 & 10 shows the variation of two blades on shaft, three blades on shaft and two blades with overlap. Figure:11 shows comparison between experimental and CFD results. The CFD analysis carried out in ANSYS FLUENT 16.2 using steady state, k-e model and it is compared with experimented conventional model which taken as reference.

## 6.0 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 3 m/s is showing high potential for developing SWT for power generation. However the existing design of conventional Savonius wind turbine is yet a matter of research to make it more useful in situations. The present work shows Savonius wind turbine having enormous potential in extracting power at low wind speed. Two scoop type SWT shows good results. As per the figure:11 shows experimental and CFD analysis both results are showing matching trend. The Savonius wind turbine has few drawbacks such as negative torque development by returning blade of the rotor and improper pressure distribution on the advancing blade.

Nomenclature:

A= swept area of the turbine,  $\text{m}^2$

COP= Coefficient of power.

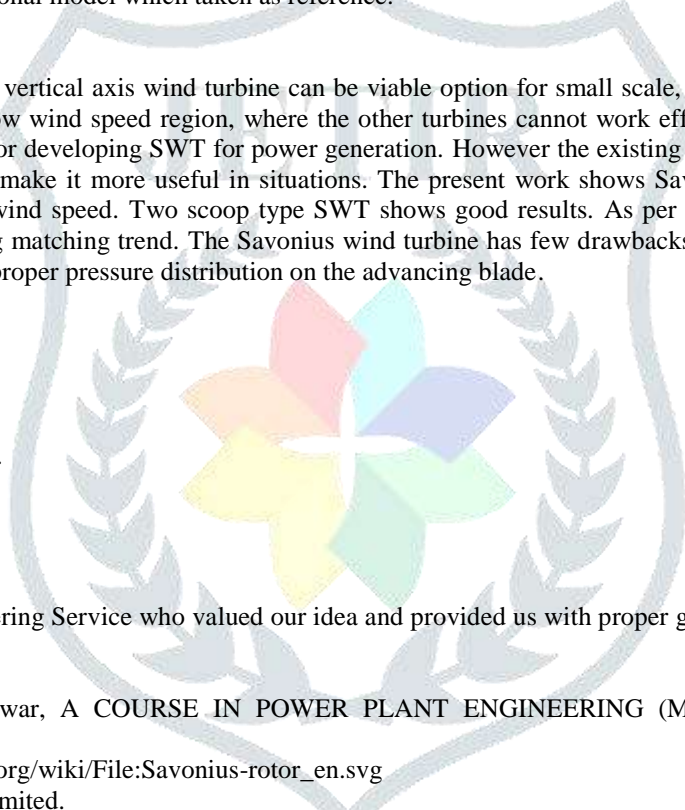
D = Diameter of turbine, m.

$P_w$ = wind Power, watt.

V= Free air Velocity at inlet m/s.

$\rho$  = Density of air,  $\text{Kg/m}^3$ .

e, S = overlap



## I. ACKNOWLEDGMENT

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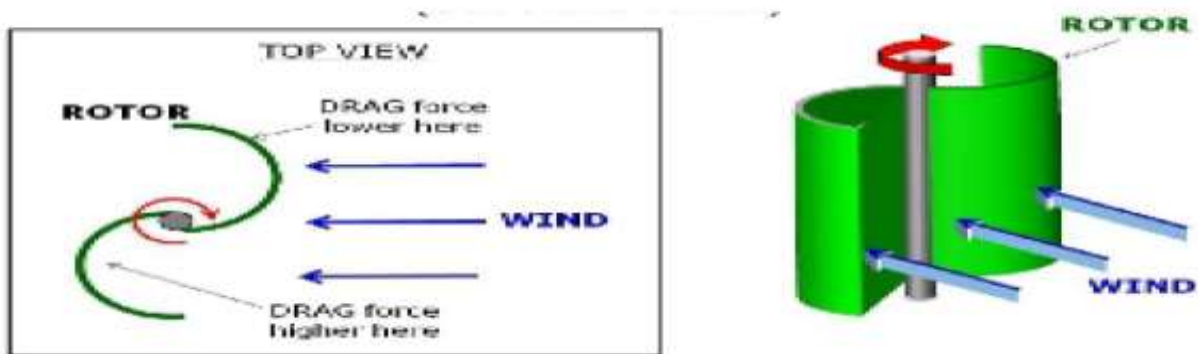


Figure:1

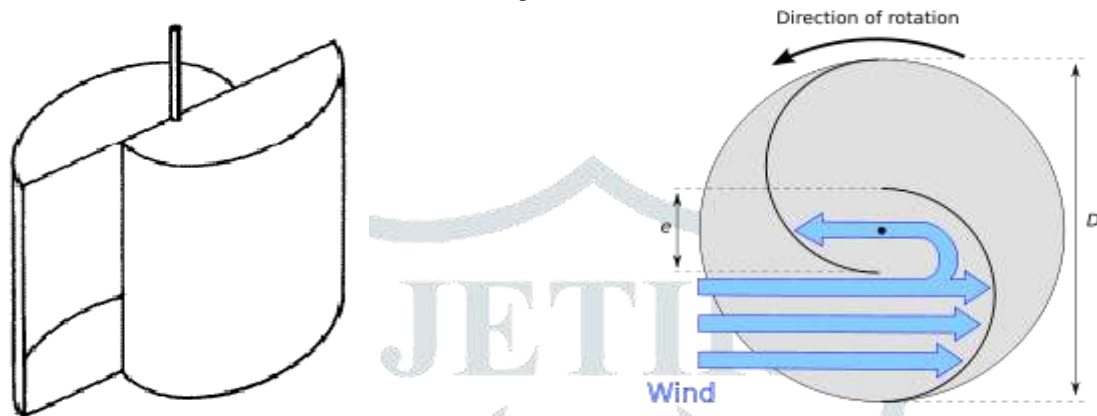


Figure:2 Schematic of a two-Scoop Savonius turbine with Operation of a Savonius Turbine

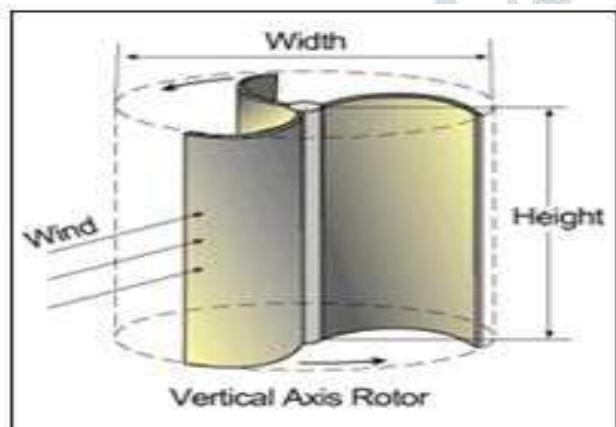


Figure:3

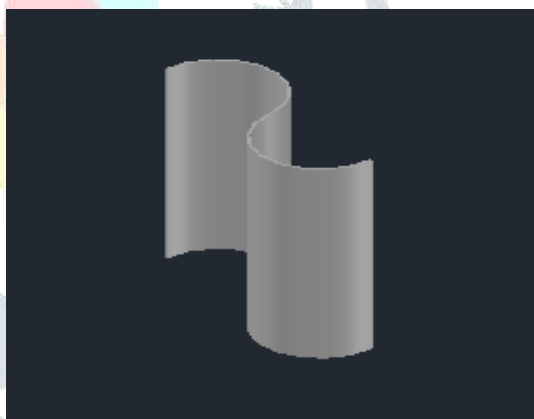


Figure:4 Savonius wind turbine with 2 blade

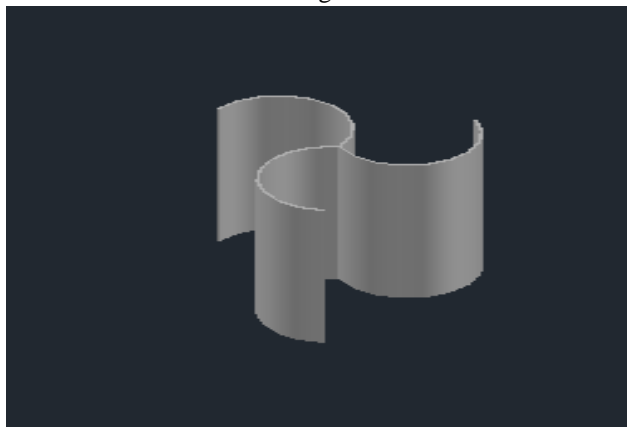


Figure:5 Savonius wind turbine with 3 blade

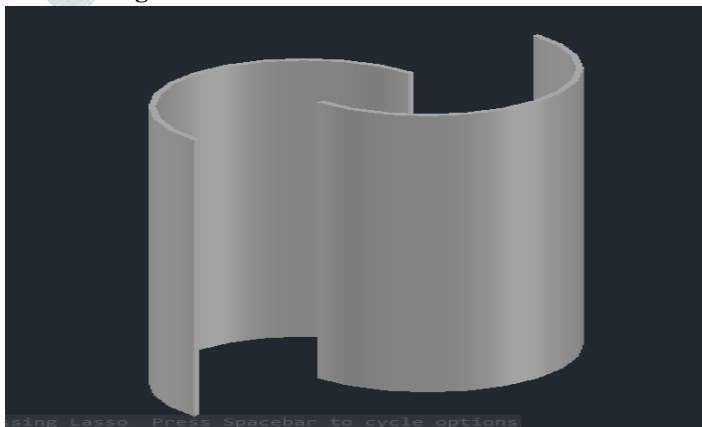


Figure:6 Savonius wind turbine with 2 blade

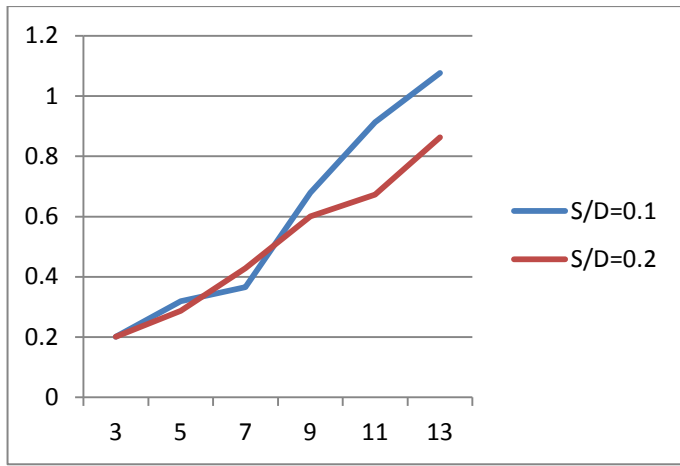


Figure: 7 Wind speed Vs torque

Velocity	Experimental Data of Turbine (W)	CFD Result of Turbine(W)
3	1.228	2.115
5	5.684	8.515
7	15.598	16.125
9	33.153	34.562
11	60.531	65.651
13	99.915	94.251

Table 2: Comparison between Results obtained

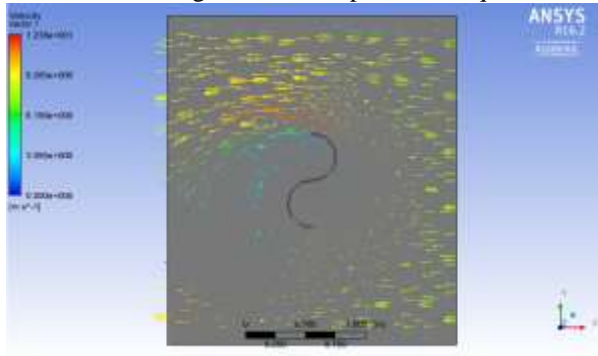


Figure:8 with velocity 3 m/s

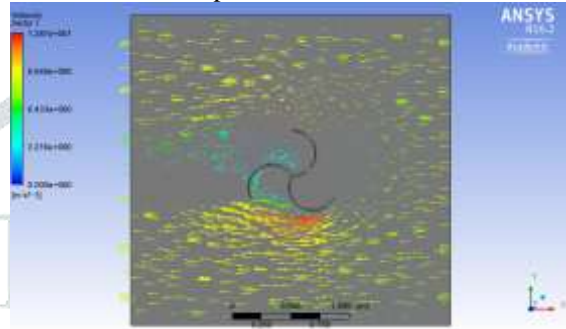


Figure:9 with velocity 3 m/s

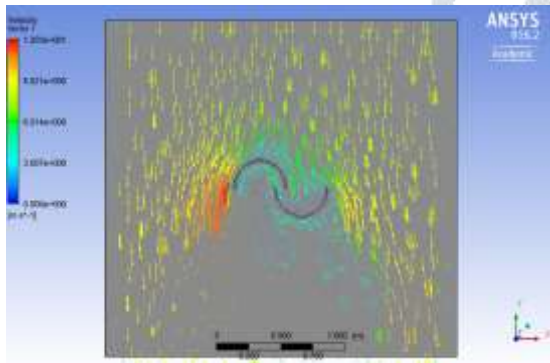


Figure: 10 with velocity 3m/s

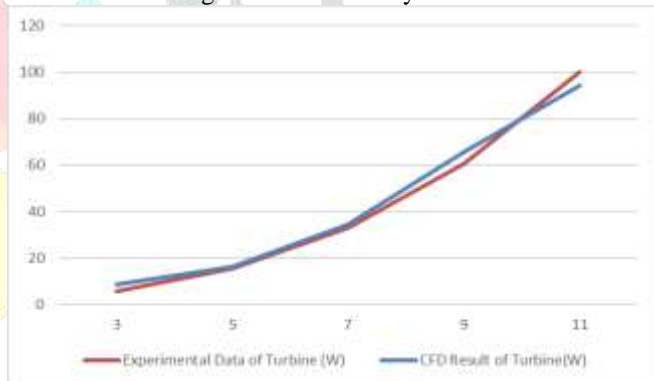


Figure:11: Wind speed v/s Power