Design, Modelling and Analysis of Savonius Vertical Axis Wind Turbine

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Abstract - *In recent times research and development especially in the field of sustainable energy i.e., wind power, solar power, etc. are considerably increased due to high pollution and high emissions by existing methods of energy generation. the horizontal axis wind turbine is generally used for commercial purposes. Therefore, for residential purpose savonius wind turbine is a good alternative which can be used to power a household as it functions in varying wind speeds and is omnidirectional. This paper aims to design and analysis of savonius vertical axis wind turbine which can generate power from wind and is used for residential purposes in rural areas affected by electricity shortage. The wind turbine is modeled in solid works and analyzed on Ansys and solid works. Following the modeling, design, and analysis savonius turbine is developed for the mentioned application.)*

Key Words: savonius turbine; sustainable energy; wind turbine; ANSYS; Solid works;

1. INTRODUCTION

This The wind is a clean and easily obtainable renewable energy resource. Each day, around the globe, wind turbines are taking the wind energy and transforming it to electricity. Wind energy production plays an important role in the way we power our earth – in a sustainable manner. India is the 4th largest wind energy producer after China, U.S and Germany. The total installation of wind power in India as on 2017 is 32 GW. A latest study by National Institute of Wind Energy has shown wind energy possible potential of 302 GW. There are two types of wind turbine: 1 horizontal axis wind turbine 2 vertical axis wind turbine. The VAWT has easy design and installation, and they can function in changing wind speeds and different direction of winds. Savonius wind turbine was invented by Finnish scientist savonius they work on principle of drag force. They look like S shape in cross section [1-4].

There are 2 forms of wind turbine: 1 HAWT (horizontal axis wind turbine) 2 VAWT (Vertical axis wind turbine). The VAWT has easy design and installation, and they can function in changing wind speeds and different direction of winds. Savonius wind turbine was created by inventor savonius they work on principle of drag force [5-7].

Tamilnadu	25%
Gujrat	20%
Maharashtra	13%
Karnataka	13%
Rajasthan	11%
Andhra pradesh	11%
Madhya pradesh	6.5%
Telangana	0.34%
Kerala	0.17%
others	0.01%

Table 1: Wind Power Installation by States in India

Designing the savonius wind turbine is complex process. Many research papers are taken into consideration while designing savonius wind turbine. Performance of wind turbine is affected by various parameters like aspect ratio, impact of number of blades and Tip Speed Ratio (TSR) [8-10]. it also gives a rough idea about difference in performance between two blade and Three or more blades savonius wind turbine due to drag force created. Different material helps in increasing performance of wind turbine like Glass Reinforced Plastic Fiber (GRPF). It helps to makes the turbine lighter which in turn improves functioning of savonius wind turbine [11-13].

Main application of designing the savonius turbine is providing electricity to rural areas where there is no electricity. So by designing this turbine it should at least provide electricity which should light up at least 2 bulbs and 1 fan running 24hrs a day.

2. DESIGN OF SAVONIUS VERTICAL AXIS WIND TURBINE

The overview of methodology of project is shown in Fig. 1.

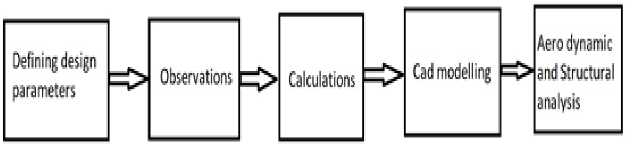

Fig. 1: **Methodology Flow Chart**

2.1 Design of parameters

Following values have been considered for designing savonius wind turbine is shown below

D	2.5m
A	3m
H	7.5 m2
Cp	0.3
λ	1
ρ	1.22
V	9m/s

2.2 Observations

The anemometer readings of different places where we personally recorded wind speed data is shown in Fig. 2

1. Bopdev Ghat - 10.27 m/s
2. Vetal Tekdi – 9.9 m/s
3. Society Terrace- 5m/s

Fig.2 Anemometer Reading

2.3 Turbine Calculations

Calculation for development of a design model for mentioned application:

1.Wind power = $\frac{1}{2} \rho A V^3$

$=\frac{1}{2} *1.22*7.5*9^3$

Pw= 3335.17W

2. Rotor power = $\frac{1}{2} \rho A V^3 Cp$

$= \frac{1}{2} *1.22*7.5*9^3*0.3$

Pr=1000.55W

3. Efficiency= Pr/Pw

=(3335.13/1000.55)*100

η =30%

4. Angular speed $\omega= \lambda* V/R$

$=1* 9/1.25$

$\omega=7.2$

5. Rotor speed= $\omega= (2 \pi n)/60$

$7.2= (2 \pi n)/60$

n= 70 rpm

3. DESIGN MODELLING AND ANALYSIS

3.1 Cad Design

All the components are modelled in Solidworks. The dimensions of each component are taken as per the amount of energy to be produced.

Cad models of shaft and blade are shown in Fig. 3 and 4

Fig.3: Shaft

The shaft has 3.4m height and 50mm diameter. These components are structurally analyzed to make sure they are safe.

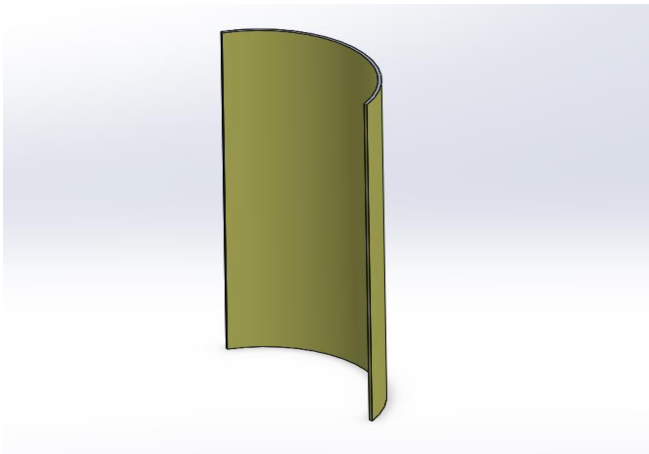

Fig. 4: Blade

The Blade is 3m in height and 20mm thickness these components are structurally analyzed to make sure they are safe.

CAD models of base plate and assemble is shown in Fig. 5 and 6

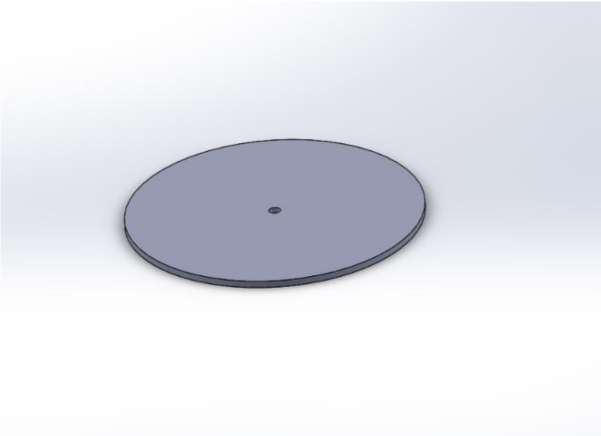

Fig. 5: Base Plate

The base plate is 2.5 in diameter and thickness of 40 mm and have been later structurally analyzed to make sure they are safe.

The dimensions of each component in assembly have been perfectly designed to generate 1 Kw of power.

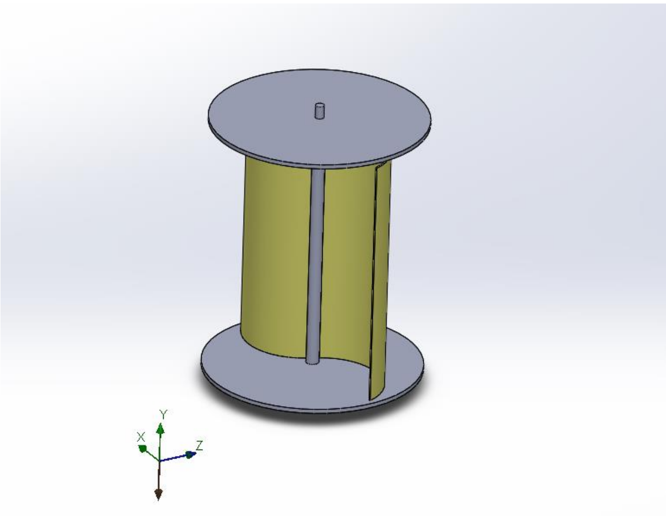

Fig. 6: Assembly

3.2 Aerodynamic Analysis

Parameters considered Velocity – 9m/s (taken from observations)

This analysis is performed on solid works flow.

1 Surface Plots:

Pressure surface plot:

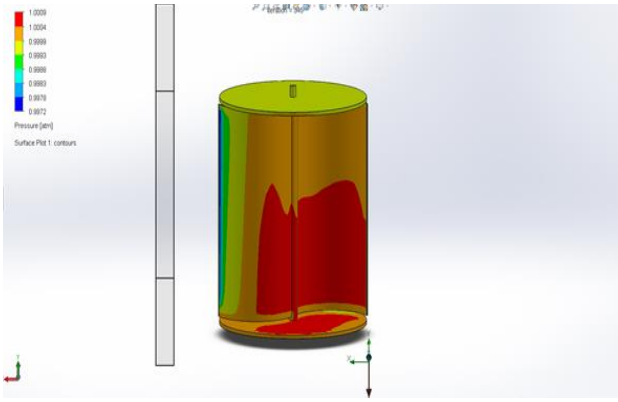

Fig. 7: Pressure Plot

In pressure surface plot it determined the pressure acting on the assembly due to 9m/s velocity. Different pressure acted on different components. The max pressure was 1.009 atm. It is shown in Fig. 7.

Temperature surface plot:

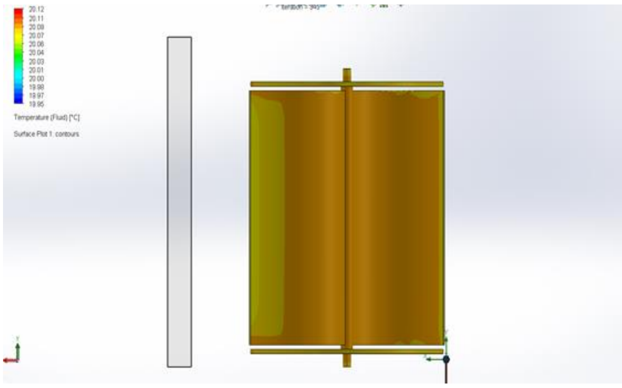

Fig. 8: Temperature Plot

In temperature surface plot it determines the temperature subjected to different parts of assembly. The temperature acting is not uniform different temperature acts on different parts of assembly. The maximum temperature was 20 °. It is shown in Fig. 8.

2 Flow Trajectories Simulation

Flow trajectories simulation which indicates the way wind behaves with the savonius turbine is shown in Fig. 9.

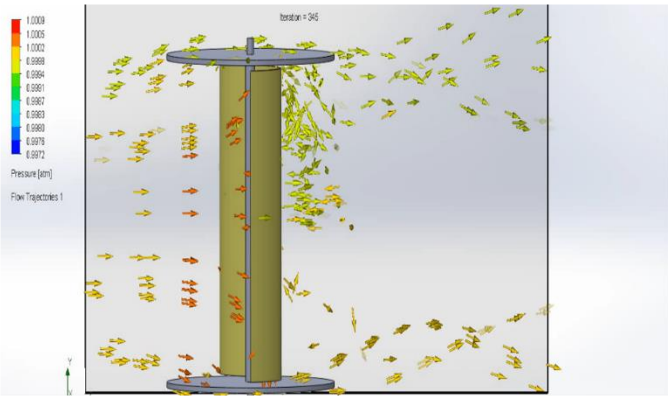

Fig. 9: Flow trajectories Simulation

We can notice drag force created around the blades of the turbine. Drag force is extremely important in this type of turbine as it works on principle of drag force.

3.3 Structural Analysis

1. Weight calculation:

Material used:

Shaft: Al alloy 6061

Blades: Al alloy 6061 sheets

Plate: Al alloy 6061

Weight calculation of assembly is shown in Fig.10.

Weight of the assembly: 910 kg (According to material used)

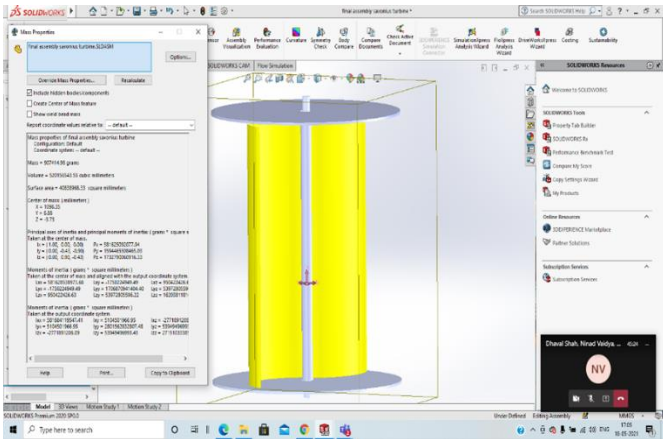

Fig. 10: Weight Calculation

2. Force calculations:

Force is applied vertically downwards on each element of assembly for static structural test.

Force= mass*gravity

F= 910*9.8

F=8918 N

Force of **10000N** is applied on each element of assembly (Just to be safe)

In static structural test two tests has been performed on each component first test is total deformation test which shows and calculate the deformation of component by applying load of 10000N in vertically downward direction and the second test is Equivalent stress test which shows the value of stress on each component after applying 10000N load.

1) Shaft

Total deformation and equivalent stress in shaft is shown in Fig. 11&12

Total deformation: max deformation - 0.0099mm

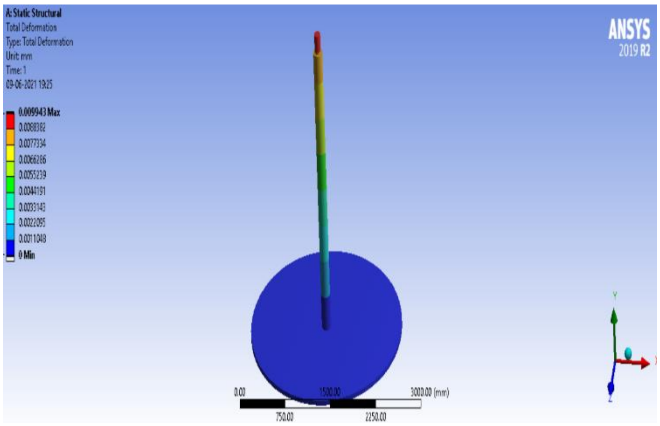

Fig. 11 Total Deformation Shaft

Equivalent stress: max stress – 1.2871 MPa

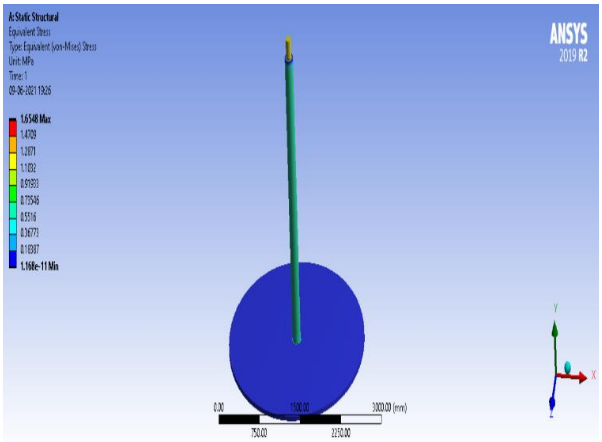

Fig. 12 Equivalent Stress Shaft

The total deformation and equivalent stress test result were good the max deformation was 0.0099mm and max stress was 1.2871 MPa which resulted that the design was safe.

2) Blade

Total deformation and equivalent stress in blade is shown in Fig. 13&14

Total deformation: max deformation=0.0067mm

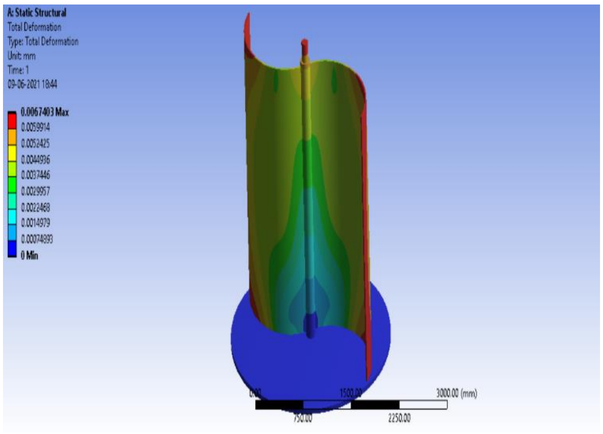

Fig. 13: Total Deformation Blade

Equivalent stress: max stress= 1.266 MPa

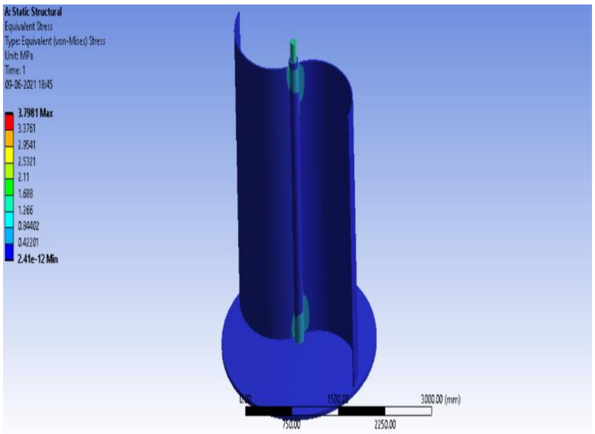

Fig. 14: Equivalent Stress Blade

The total deformation and equivalent stress test result were good the max deformation was 0.0067mm and max stress was 1.266 MPa which resulted that the design was safe.

3) Base Plate

Total deformation and equivalent stress in plate is shown in Fig. 15&16

Total deformation: max deformation=0.000568

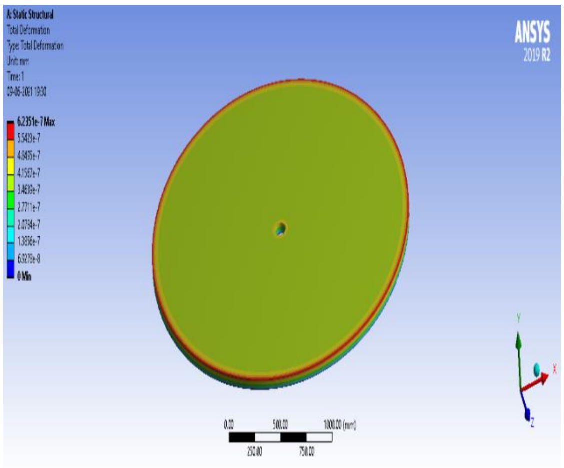

Fig. 15: Total Deformation Plate

Equivalent stress: max stress = 0.00293MPa

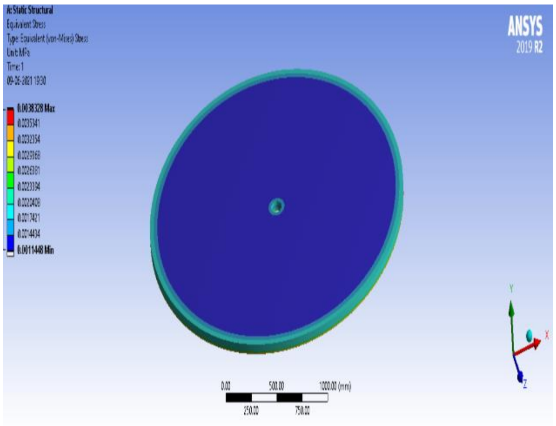

Fig. 16: Equivalent Stress Plate

The total deformation and equivalent stress test result were good the max deformation was 0.000568mm and max stress was 0.00293 MPa which resulted that the design was safe.

4. RESULT AND DISCUSSION

4.1 Design Calculation Result

Table 2 Design Calculation Result

Pw (wind power)	**3335.17 W**
Pr (Rotor power)	**1000.55 W**
η (efficiency)	**30%**
ω (Angular speed)	**7.2 rad/sec**
N (rotor rpm)	**70 Rpm**

Table 2 shows manual calculation results which indicates power generated is 1 KW

4.2 Aerodynamic Results

1) Surface Plot Results

Table 3 Surface Plot Results

Surface plots	Temperature surface plot	Pressure surface plot
Max value	**20.12°c**	**1.009 atm**
Min value	**19.95°c**	**0.9972 atm**

Table 3 shows Surface plots determine the pressure and temperature acting on different components of turbine and the maximum value and minimum value of temperature and pressure acting on different parts.

2) Flow Simulation Result Graph

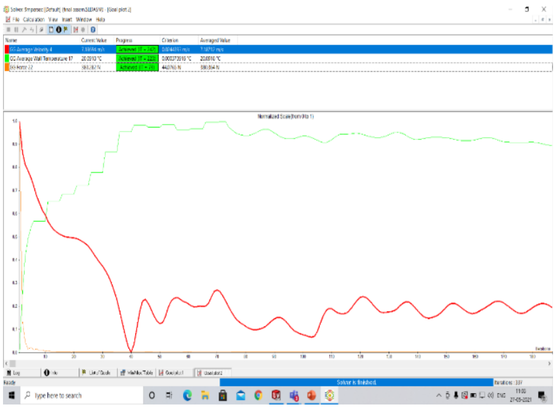

Fig. 17: Flow Simulation Result

Fig. 17 is the graph of aerodynamic analysis which indicates Average velocity, wall temperature and maximum force acting on savonius turbine. The Table 4 below indicates the results obtained from graph

Table 4: Flow Simulation Result

Average velocity	7.15 m/s
Average wall temperature	20 degree c
Maximum force	380 N

4.3 Structural Analysis Results

Table 5: Structural Analysis Results

	Shaft	Blade	Base
Maximum total deformation	0.0099mm	0.0067mm	0.000568mm
Maximum equivalent stress	1.2871 MPa	1.266 MPa	0.00293 MPa

Table 5 shows structural analysis it was determined that there was no considerable deformation, and the design was safe.

5. CONCLUSIONS

1. The turbine is designed for the perfect rotor speed (ie 70 rpm) as it is a drag type turbine it rotates at rather low rpm compared to other vertical axis wind turbines.
2. This turbine produces 1 KW/hr of power at 9 m/s speed which is perfect for a Self-sufficient house and it can supply energy 24hrs a day.
3. The wind data is taken personally for the site using anemometer and not from wind speed data web sites which makes it more practical.
4. It has been modelled using solid works and has been analysed aerodynamically using solid works flow software and structurally analysed by using ANSYS

6. REFERENCES

[1] Sargolzaei and A. Kianifar (2007), Estimation of the Power Ratio and Torque in Wind Turbine Savonius Rotors Using Artificial Neural Networks , International Journal of Energy, Issue 2, Vol. 1, pp 33-50.

[2] Harsanto, T., Prananto, H.D., Budi, E., & Nasbey, H. (2015). Design and Construction of Vertical Axis Wind Turbine Triple-Stage Savonius Type as the Alternative Wind Power Plant, New, Renewable Energy and Energy Conservation Conference and Exhibition (The 3rd Indonesia EBTKE-ConEx, 2014), Vol. 2, pp 172-175.

[3] Samir Deshmukh and Sagar Charthal. (2017). Design and Development of Vertical Axis Wind Turbine. IRA-International Journal of Technology & Engineering, Proceedings of the International Conference on Science & Engineering for Sustainable Development, pp 286-194.

[4] Mohammed Hadi Ali (2013), Experimental Comparison Study for Savonius Wind Turbine of Two & Three Blades at Low Wind Speed, IJMER, Vol. 3, Issue. 5, pp-2978-2986.

[5]] M. Sunil Kumar VVSH Prasad C. Labesh Kumar, (2017), Savonius Wind Turbine Design and Validation-An Manufacturing Approach, International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 9, pp. 18–25.

[6] Ashwin Dhote, Prof. Vaibhav Bankar (2015), Design, Analysis and Fabrication of Savonius Vertical Axis Wind Turbine, International Research Journal of Engineering and Technology (IRJET), Vol. 2, Issue3, pp 2048-2054.

[7] Hnin Yu Yu Kyaw, Ei Cho Cho Theik, Khaing Zar Nyunt (2019) Design and Fabrication of H-Darrieus VAWT International Journal of trends in Scientific Research and Development (IJTSRD), Volume 3, Issue 4, pp 1570.

[8] J. Pulfer, W. Meza, F. Mitjans, J.Gonzalez (2018), Energy Efficiency Assessment of Four Designs of Vertical Axis and Drag Differential Wind Turbines, IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 13, Issue 1, Ver IV, pp 73-81.

[9] Saurabh Arun Kulkarni and Prof. M.R. Birajdar, (2016) Vertical Axis Wind Turbine for Highway Application, Empirical Journal of Interdisciplinary Research (IJIR), Vol 2, Issue 10, pp 1543-1546.

[10] Piyush Gulve and **Dr. S. B. Barve (2014)**, Design and Construction of Vertical Axis Wind Turbine, International Journal of Mechanical Engineering and Technology (IJMET), Volume 5, Issue 10, pp. 148-155.

[11] Bhushan D. Agarkar and **Shivprakash B. Barve (2016)**, A Review on Hybrid solar/wind/ hydro power generation system, International Journal of Current Engineering and Technology', Special Issue-4, pp 188.

[12] Ninad Vaidya and Dr. Shivprakash Barve (2021), Design, Modelling and Comparative Analysis of a Horizontal Axis Wind Turbine, International Research Journal of Engineering and Technology (IRJET), Volume 8, Issue 8, pp 808-815.

[13] Dhaval S. Shah and Shivprakash B. Barve (2021), Design, Analysis and Simulation of a Darrieus (Eggbeater type) Wind Turbine, Journal of Engineering and Technology (IRJET), Volume 8, Issue 10, pp 1655-1660.