Design of Hybrid Solar Wind turbine System with CFD Analysis

[1] Dr. Imran Ahmed Khan, [2] Ankush Sudhakar Karemore, [3] Rajat Prakashrao Kurhade
[1]Associate Prof., [2]Student, [3]Student
[1]Mechanical Department of Engineering,
[1]Priyadarshini College of Engineering, Nagpur, Maharashtra

Abstract - The projects aims to evaluate the aerodynamic performance of variable speed of Vertical axis wind turbine blades through three dimensional computational fluid dynamics analysis. A wind turbine is a device that converts kinetic energy from the wind into electrical power. With the shortage of fossil fuel and increase of environmental awareness solar and wind energy is becoming more popular as well as important than ever. The investigation carried out with wind turbine to find efficient velocities to obtained optimum power generation. Also it increases the reliability and reduces the dependence on one single source. This hybrid solar wind power generating system is suitable for industries and also domestic areas. The present work is focused on the design of hybrid solar wind turbine system with different velocities i.e. 2meter per second, 5meter per second, 8meter per second.

Keywords - Wind turbine, Turbulence modeling, Aerodynamics modeling.

I. INTRODUCTION

We all know that the world is facing a major threat of fast depletion of the fossil fuel reserves. Most of the present energy demand is met by fossil and nuclear power plants. A small part is met by renewable energy technologies such as the wind, solar, biomass, geothermal etc. There will soon be a time when we will face a severe fuel shortage. As per the law of conservation of energy, "Energy can neither be created, nor be destroyed, but it can only be converted from one form to another". Most of the research now is about how to conserve the energy and how to utilize the energy in a better way. Wind energy systems convert this kinetic energy to more useful forms of power [1]. Wind energy systems for irrigation and milling have been in use since ancient times and at the beginning of the 20th century it is being used to generate electric power. Windmills for water pumping have been installed in many countries particularly in the rural areas. Wind turbines transform the energy in the wind into mechanical power, which can then be used directly for grinding etc. or further converting to electric power to generate electricity.

Hybrid power system consist of a combination of renewable energy source such as wind generators, solar etc. of charge batteries and provide power to meet the energy demand, considering the local geography and other details of the place of installation. These types of systems are not connected to the main utility grid. They are also used in stand-alone applications and operate independently and reliably. The best application for these types of systems is in remote places, such as rural villages, in telecommunications etc. The importance of hybrid systems has grown as they appear to be the right solution for a clean and distributed energy production. The escalation in cost and environmental concerns involving conventional electrical energy. Sources have increased interest in renewable energy sources [2]. Many societies across the world in which we live have developed a large appetite for electrical energy. This appetite has been stimulated by the relative ease with which electricity can be generated, distributed, and utilized, and by the great variety of its applications.

Hydro-power generation is restricted to geographically suitable areas, and reserves of coal, although presently plentiful, are not renewable. Wind solar power generations are visible options for future power generation. Besides being free, they are free of recurring costs. They also offer power supply solutions for remote areas, not accessible by grid power supply today around 30,000 wind turbines and more than 1,00,000 off-grid solar PV systems are installed all over the world. Wind and solar hybrid model with proper storage system have been keen interest for the last few years. In this project a hybrid model of solar/wind is developed using the battery. The simulation circuit will include all realistic components of the system [4].

II. ANALYTICAL CALCULATION

1) Underlying Concept:

The main principle of a VAWT is its capability to utilize the power of the wind and convert it into mechanical power. The power of the wind is similar to the power of a turbine in general [5].

The equation for wind power is:

$P_{wind} = ½ * \rho * A * v^3$

Where; P is power output (volts),

ρ is air density (kg/m3), approximately 1.207 kg/m3,

A is swept area (m^2), which is equal to diameter*height (m^2), and

v is undisturbed wind speed (m/s).

When we calculated the power of the turbine from our readings from the motor, we used the following equation:

$P_{turbine} = V^2 / R$

Where; V is voltage (V) and
R is resistance (Ω).

The conversion of wind power into mechanical power is dependent of the efficiency of the windmill. This is represented by the coefficient of performance, Cp which takes into account the angle of the blades and the rotational speed of the windmill.

The equation for Cp is
$Cp = P_{turbine} / P_{wind}$

Where; $P_{turbine}$ is the power of the turbine (watts)
P_{wind} is the power of wind (watts)

The equation for power of a turbine is:

$P = ½ * Cp * \rho * A V^3$

Where; P is power output (volts),
ρ is air density (kg/m3), approximately 1.207 kg/m3,
A is swept area (m2), which is equal to diameter*height (m2),
v is undisturbed wind speed (m/s), and
Cp is power coefficient.

The physical testing determined the coefficient of performance and subsequently, the turbine's efficiency. Although different variations of blade angles or amount of scoops would change the efficiency, the efficiency found was much lower than expected. The effectiveness of the motor, the slipping of the rubber band that spun the motor, and the friction caused along the axis are all to impugn for this [8].

2) Diametric Representation of Blade:

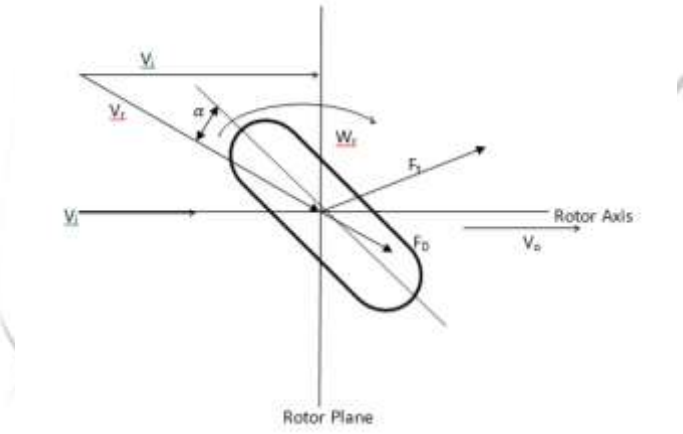
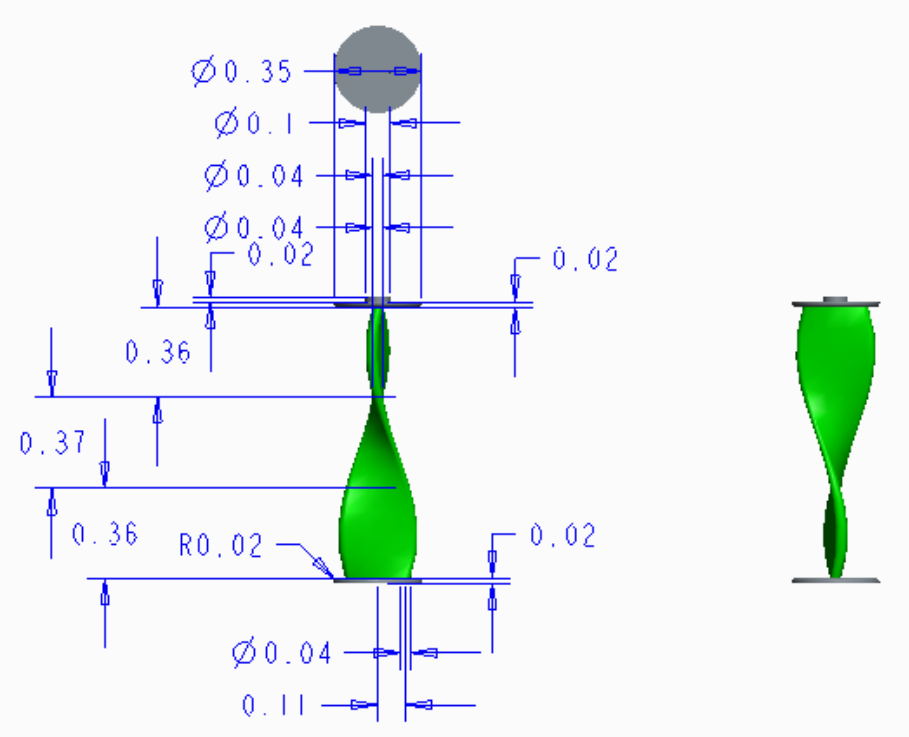


Fig.: Diametric representation of Blade

Nomenclature;

V_i	=	Inlet wind velocity
α	=	Angle of attack
ω	=	Blade angular velocity
r	=	Blade radius
V_r	=	Resultant wind velocity
ρ	=	Air density
F_L	=	Lift Force
F_D	=	Drag Force
N	=	Speed of wind turbine
C_L	=	Coefficient of lift
C_D	=	Coefficient of drag
C_P	=	Coefficient of performance
P_N	=	Numerical Power value
P_A	=	Analytical Power value



III. CONTROL EQUATION:

As the wind turbines Mach number at work is typically less than 0.3, so the flow around the airfoil could be considered as incompressible flow, the two dimensional incompressible N-S equations and two dimensional continuity equation are used as the control equations.

The two dimensional incompressible N-S equation is expressed in vector as follows:

$$\rho \frac{DV}{Dt} = \rho f - \nabla p + \mu \nabla^2 V$$

Where V is the velocity vector, f is the volume force vector, μ is the dynamic viscosity.
The continuity equation is showed as follows:

$$\nabla . V = o$$

Compared with the conventional k-ε turbulence model, the content on rotation and curvature is added to the Realizable k-ε model for the calculation of turbulence dynamic viscosity, and the equation of the dissipation rate ε is amended. Therefore, the model been shown that could simulate the flow around a blunt body effectively. Reynolds averaged equations and continuity equations are showed as follows:

$$\frac{\partial \overline{u_i}}{\partial t} + \overline{u_i} \frac{\partial \overline{u_i}}{\partial x_i} = -\frac{\partial \overline{p}}{\partial x_i} + \frac{\partial}{\partial x_j}[\nu \frac{\partial \overline{u_i}}{\partial x_j} - \rho \overline{u_i u_j}]$$

$$\frac{\partial \overline{u_i}}{\partial x_i} = 0$$

The mode equations of the turbulent kinetic energy k and turbulent kinetic energy dissipation rate ε are:

$$\frac{\partial k}{\partial t} + \overline{u_i} \frac{\partial k}{\partial x_j} = \frac{\partial}{\partial x_i}\left[\left(\nu + \frac{\nu_t}{\sigma_t}\right)\frac{\partial k}{\partial x_j}\right] + \left(\frac{\partial \overline{u_i}}{\partial x_j} + \frac{\partial \overline{u_j}}{\partial x_j}\right)\frac{\partial u_j}{\partial x_j} - \varepsilon$$

$$\frac{\partial(\rho\varepsilon)}{\partial t} + \frac{\partial(\rho \overline{u_i}\varepsilon)}{\partial x_i} = \frac{\partial}{\partial x_i}\left[\left(\nu + \frac{\nu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + c_1 \rho s \varepsilon - c_2 \rho \frac{\varepsilon^2}{k + \sqrt{\nu\varepsilon}}$$

Realizable k –ε model has been widely used in various types of flow simulation, which includes Rotational average shear flow, free flow including jet and mixed flow, flow in pipes, boundary layer flow and backward-facing step flow, the result is consistent with the experimental data.

IV. NUMERICAL ANALYSIS:

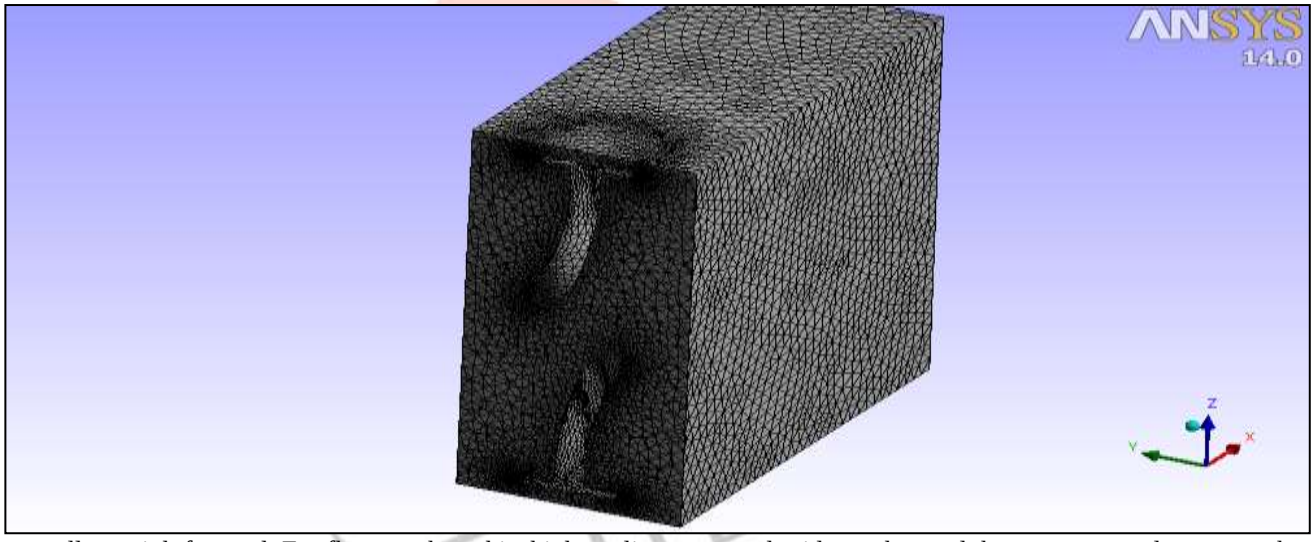
ANSYS CFX 14.0 was used as finite volume based solver, for solving the governing equation and implementing the boundary conditions. For solving numerical problems through CFD the common procedure followed is.

1. Pre-processing

In this very first stage of numerical analysis a solid model of vertical axis wind turbine was created, using Creo Parametric 2.0 as modelling software and an unstructured triangular mesh was created using ANSYS ICEM with 0.009 mm as element size.

2. Processing or Solving

After the geometry for the VAWT had been defined, the next step is to discretize the computational domain as a preprocessing step in the CFD process. The act of discretizing the domain is termed grid generation and is one of the most important steps in the CFD process. For simple geometries where the direction of the flow is known beforehand, creating the



grid is usually straightforward. For flows such as this, high quality structured grids can be used that can accurately capture the flow physics. However, as geometry becomes complex and the flows more difficult to predict with the onset of turbulence and separation, grid generation is no longer a trivial task.

3. Post-processing

Post-processing is interpretation and visualization of simulation results. During post processing the mass imbalances is checked for physical soundness of the simulated results. Hence, various visualization techniques such as, Contour plots, Streamline plots, Vector plots, X-Y plots are used for further analysis. Post processing was done with help of Fluent 14.0, CFX, Ansys CFD-Post, etc.

V. RESULT AND DISCUSSION

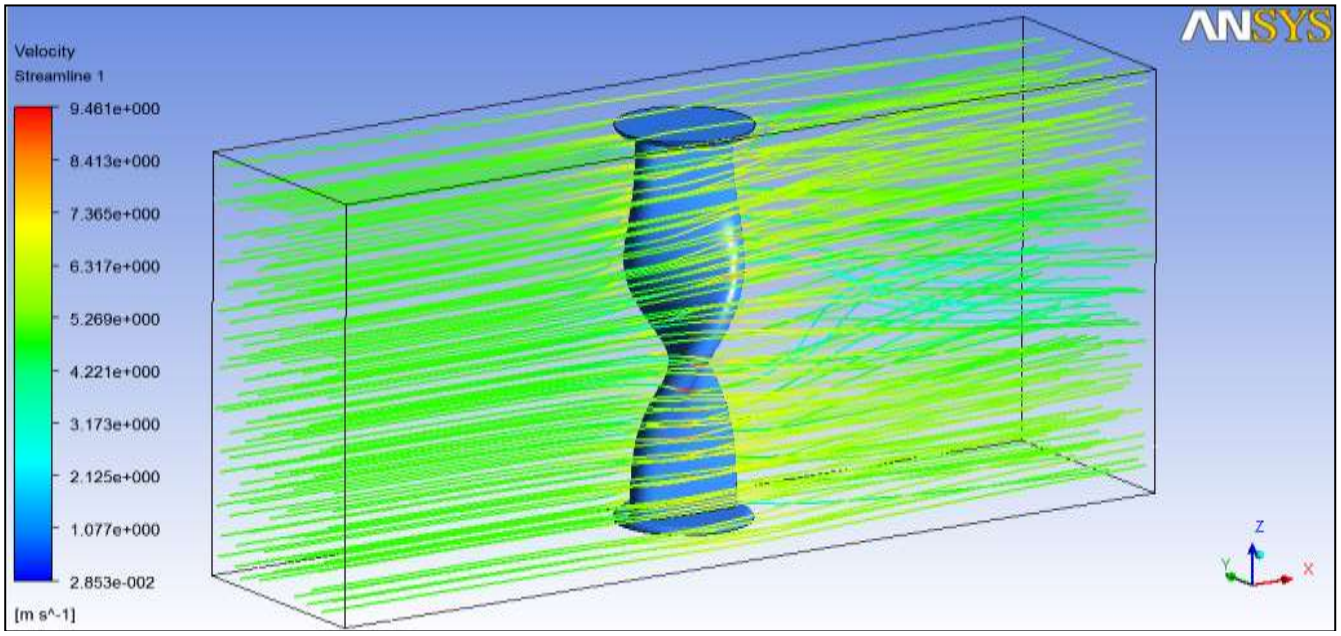
To design of hybrid solar wind turbine system with different velocities i.e. 2meter per second, 5meter per second, 8meter Per second. The investigation carried out with wind turbine to find efficient velocities to obtained optimum power generation i.e. 5 meter per second.

In this project, we work on different wind velocities extract in wind turbine and analyzed using CFD-CFX software are as :

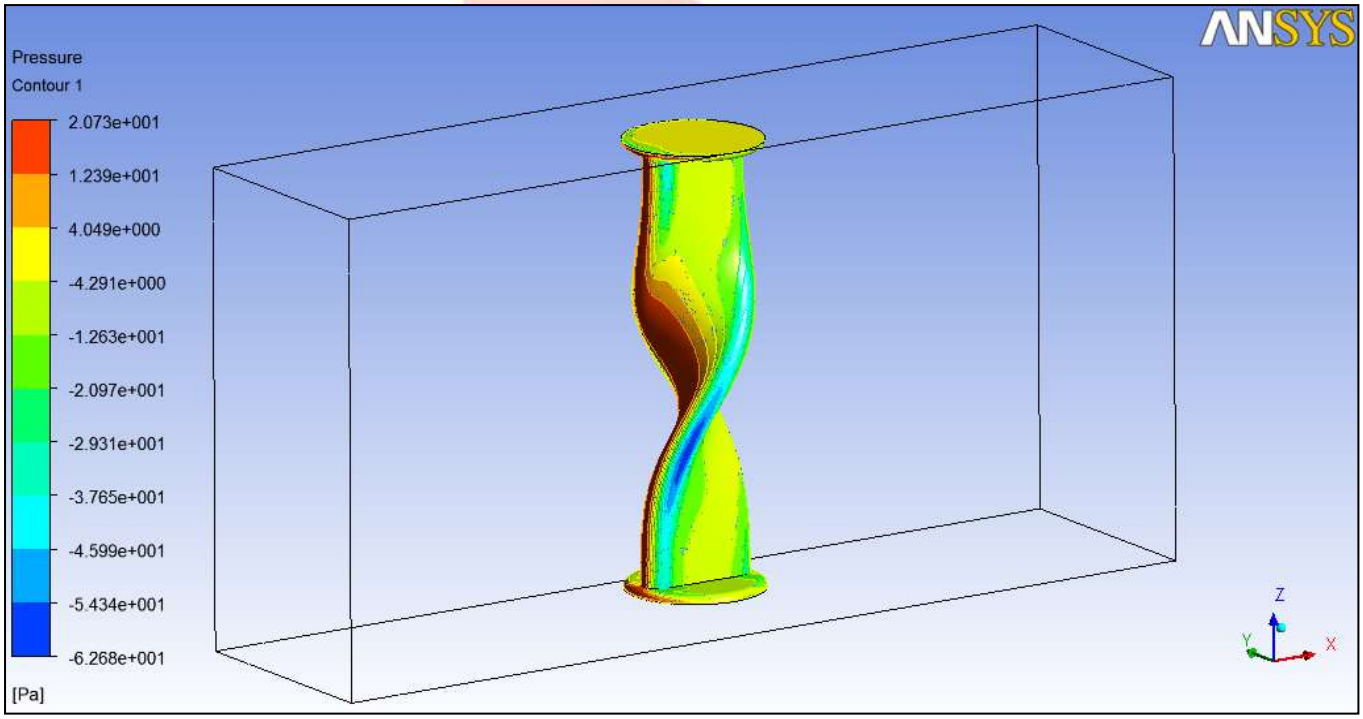
Result

Wind Velocity = 5 m/s

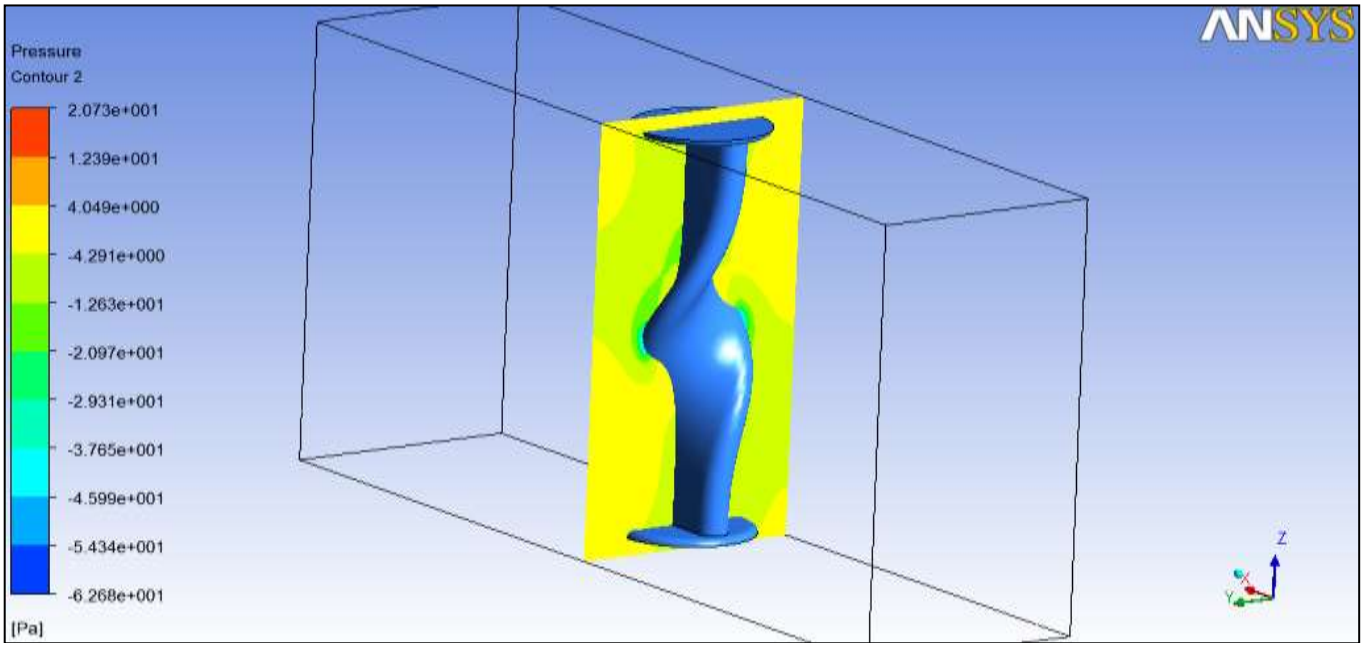
Velocity Streamline:



Pressure at Blade Surface:



Pressure at c/s 0f Blade:



CONCLUSIONS

In this project, Hybrid power generation system is good and effective solution for power generation than conventional energy resources. It has greater efficiency. It can provide to remote places where government is unable to reach. So that the power can be utilize where it generated so that it will reduce the transmission losses and cost. Cost reduction can be done by increasing the production of the equipment. People should motivate to use the non-conventional energy resources. It is highly safe for the environment as it doesn't produce any emission and harmful waste product like conventional energy resources. It is cost effective solution for generation. It only need initial investment. It has also long life span. Overall it is good, reliable and affordable solution for electricity generation.

A Solar PV Wind Hybrid Energy System was implemented. A portion of the energy requirement for a private house, farm house, a small company, an educational institution or an apartment house depending on the need at the site where used has been supplied with the electricity generated from the wind and solar power. It reduces the dependence on one single source and has increased the reliability. Hence we could improve the efficiency of the system as compared with their individual mode of generation [9].

REFERENCES

[1] Adejumobi, S.G. Oyagbinrin, F. G. Akinboro & M.B. Olajide, "Hybrid Solar and Wind Power: An Essential for Information Communication Technology Infrastructure and people in rural communities", IJRRAS, Volume 9, Issue1, October 2011, pp 130-138.

[2] Kavita Sharma, Prateek Haksar "Designing of Hybrid Power Generation System using Wind Energy Photovoltaic Solar Energy Solar Energy with Nanoantenna" Internationa Journal of Engineering Research And Applications (IJERA) Vol. 2, Issue 1,Jan-Feb 2012, pp.812-815.

[3] Sandeep Kumar, Vijay Kumar Garg, "A Hybrid model of Solar-Wind Power Generation System", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE), Vol. 2, Issue 8, August 2013, pp. 4107-4016.

[4] C.G. Justus, W.R. Hargraves, and A. Yalcin, Nationwide assessment of potential output from wind power generators, J. Appl. Meteor. 15, 673-678. (1976)

[5] S.O. Enibe. A Method of Assessing the Wind Energy Potential in a Nigerian Location. Nigerian Journal of Solar Energy. 6, 14-20. (1987),

[6] V.Quaschning. "Understanding Renewable Energy Systems". Earthscan, London. (2005),

[7] I.A. Adejumobi. "Solar Energy for Hospital and Other Services (Banking and Information Communication Technology (ICT) in Rural Communities, Workshop Seminar Paper, International Training School and Workshop on Solar Energy, Organized at University of Agriculture, Abeokuta,9th-11th June, 11-17. (2009)

[8] Arjun A. K., Athul S., Mohamed Ayub, Neethu Ramesh, and Anith Krishnan," Micro-Hybrid Power Systems – A Feasibility Study",

[9] Journal of Clean Energy Technologies, Vol. 1, No. 1, January 2013, pp27-32. J.B.V.SUBRAHMANYAM, P. K. Sahoo and Madhukarreddy," Local PV-Wind hybrid systems development for supplying electricity to industry" Acta Electrotechnica, Vol.53,No.1,2012,pp10-15.

[10] N. Sivaramakrishna & Ch. Kasi Ramakrishna Reddy," Hybrid Power Generation through combined solar –Wind power and modified solar panel" International Journal of Engineering Trends and Technology (IJETT) - Volume4Issue5- May 2013,pp1414-1417.

[11] U_ur FESL, Raif BAYIR, Mahmut OZER, ”Design and Implementation of a Domestic Solar-Wind Hybrid Energy System”, 2010 pp29-33.
[12] www.accessengineeringlibrary.com/browse/handbook-of-energy-engineeringcalculations.