International Journal of Current Engineering and Technology
©2016 INPRESSCO®, All Rights Reserved

E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Design of Multi-rotor Wind Turbine with Solar Hybrid System

Nilesh Mane[‡]*, Prasad Mane[‡], Kapil Sabale[‡] and Mayura Mokashi[†]

[†]Mechanical Engineering Department, Marathwada Mitra Mandal's Institute of Technology, SPPU, Pune-47, India

Accepted 01 Oct 2016, Available online 05 Oct 2016, **Special Issue-6 (Oct 2016)**

Abstract

The current generation wind turbines are upscale into multi megawatt range in terms of output power. However, the energy benefit from the turbine is offset by the increased mass and cost. 20 MW wind turbines are now feasible with rotor diameters up to 200 m, according to a new report from the EU-funded upwind project in 2011. The question is, how much bigger can wind turbines get realistically? One concept worth considering, and the one that is the subject of this project, is to have more than one rotor on a single support structure. Such turbines could have a greater power to weight ratio. Multi-rotor systems also offer the advantage of standardization, transportation and ease of installation and maintenance. In this thesis, 15W single rotor baseline wind turbine is compared with a 15 W multi-rotor wind turbine. The multiple rotors are downscaled using scaling curves

Keywords: *Upwind, Power to weight ratio, Multi-rotor, Downscaled, Scaling curves*

1. Introduction

Wind energy converters are not a new technology and have been utilized for mainly mechanical applications such as grain crushing since 644 A.D. The first wind mills were vertical axis turbines which used sails around a pivot to create mechanical power. Centuries after the Persian wind mill technology was documented news of the Chinese utilizing wind mills to drain their rice paddies of water reached Europe. Whether or not the Chinese had already been utilizing the windmill or a run-off of a wind mill before the Persians can no longer be determined with certainty today. Interestingly, the Chinese wind mill was also a vertical axis bamboo structure with sails, similar to the Persian system. The classical or horizontal axis wind turbine can be confidently attributed to European designers independent of the oriental vertical axis systems (Peter J. Schubel and Richard J. Crossley *et al* 1996). The first documented historical evidence of horizontal axis wind mills dates back to 1180 which tells of a wind mill called a post or trestle mill present in the Dutch Normandy. From there on the post mill quickly spread throughout Europe and was then further developed into the tower mill two centuries later. In the 16th century the Dutch wind mill was developed in Holland which composed of a mill house with a rotating tower cap and rotor blades.

La Cour's wind turbines were the beginning of a new era of electricity production and his success was highlighted when the Lykkegard Company started to industrially evaluate his developments. Lykkegard began the production of electricity generating wind turbines modeled after the developments made by La Cour at his testing station at Askov. The rising fuel prices encountered during World War 1 brought about acceleration in the production of the wind turbines and by 1918 about 120 electricity producing wind turbines were in operation around Europe (Qunwu Huang, Yeqiang Shi , Yiping Wang , Linping Lu , Yong Cui *et al* 2014). The La Cour Lykkegard turbines were produced in a range of sizes with power production ranging from 10-35 kW. The design incorporated fan blades with shutters which made it possible to remain below a certain critical rotational speed limit and operate at a safe level and yawing was managed by two fan tails. The electrical generator was positioned at the base of the tower and was connected to the rotor shaft by a vertical drive shaft and intermediate gearbox.

Attempts have been made to optimize the array size of PV systems employed in hybrid power generation systems. Probability density function of the wind speed and irradiance for each hour of a typical day in a month has been found. By using least square method, the best fit of the PV array and wind turbine for a given load has been determined and an algorithm has been developed to find the optimum size of the PV array. In hybrid power generation systems, the available energy from the PV-wind system decides the size of the battery bank in such a way that the system will satisfy the load demand at any hour of a typical day.

For estimating the energy performance of hybrid system, the reliability analysis is performed by the use of the energy index of reliability. The model enables

---

*Corresponding author: **Nilesh Mane**

the study of range periods from one year to one hour, thus allowing the inclusion of time value of energy as appropriate in economical assessment (Qiyue Song, *et al* 2012). The model is validated by an illustrious numerical example and the results are compared to those resulting from the time domain simulation. A statistical approach alternative to a time step simulation is used for the evaluation of long-term average performance of a hybrid system.

2. System Development

2.1. Theoretical Methodology

- A Power to produce from project 50-55w
- Number of wind turbine:3
- Power producing capacity from single turbine:15W

2.2. Parameters

- Standard air density:1.23 kg/m^3
- Air velocity: 18km/hr

For single turbine rotor with 15W Power Betz developed a simple model to predict the performance of ship propellers and this model is widely used to demonstrate the principle of wind turbines. He assumed the air was one dimensional, incompressible, and time-invariant, and then with the principle of conversation of momentum, the force T on the wind turbine was thrust through the profile.

The power output of a wind turbine is usually characterized by the power curve, the relationship between undisturbed wind speed at the hub height of the turbine, and the power output of the turbine. The power curve is the primary means of characterizing the performance of a turbine. A typical power curve is shown in Fig. Cut-in speed is the minimum speed at which the wind turbine starts working; cut-out speed is the maximum wind speed at which the turbine can produce energy; the rated point is the wind speed at which the wind turbine outputs the rated power. Generally, output power of a wind turbine is calculated by

$C_p = P/0.5\rho AV^3$(1)

From which he concluded that one could get C_{PMax} = 0.5926, this is the Betz limit. No practical wind turbine reaches this limit for it is the theoretically maximum power coefficient.

Power Generated by turbine

$P= 1/2\left(\rho AV^3 C_p\right)$(2)

Where,
ρ =Air density (1.23kg/m3)
A=Swept Area
V=Velocity

With the use of these equations radius of turbine and length is calculated

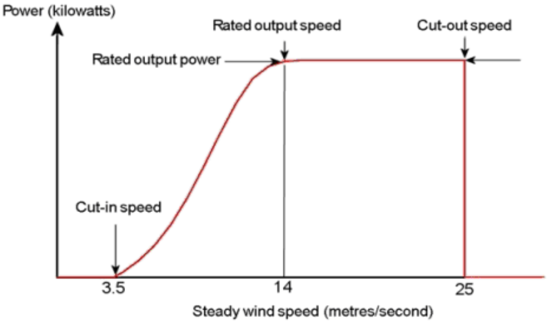

Fig.1 (power curve)

2.3. Tip Speed Ratio

Tip speed ratio is given by,

$\lambda = \Omega r/V_w$(3)

Where,
Vw -Wind speed (5m/s)
r –Radius
Ω-Rotational velocity (rad/s)
λ -Tip speed ratio

Modern HAWT generally utilize a tip speed ratio of nine to ten for two bladed rotors and six to nine for three blades. Taking tip speed ratio minimum for 3 rotor blade as 6(Sandeep Kumar, Vijay Kumar Garg, *et al* 2013). Then the theoretical speed calculated is 881.47 rpm.

Torque available for a one turbine is given by,

$T=0.5\rho AV^2 r$(4)

The basic wind speed (V) for any site shall be obtained from and shall be modified to include the following effects to get design wind velocity at any height for the chosen structure

a) Risk level;
b) Terrain roughness, height and size of structure;
c) Local topography.

It can be mathematically expressed as follows:
Design wind speed is given by,

$U_w = V\times k1\times k2\times k3$(5)

Where,
k1=risk factor (1)
k2=Height factor (1.05)
k3=Topography factor (1)
Local resultant air velocity is given by,

$V_r = \sqrt{V_w^2 + U^2}$(6)

According to betz limit twisting angle for blade is taken as generally 2, 5, and 7. Aspects such as efficiency, torque, mechanical stress, aerodynamics and noise should be considered in selecting the appropriate tip speed. The efficiency of a turbine can be increased with higher tip speeds, although the increase is not significant when considering some penalties such as increased noise, aerodynamic and centrifugal stress.

Chord length or width of blade is given by

$$C_{opt} = [2\Pi r/n] \times [8/9]C_L \times [U_{wd}/\lambda V_r](7)$$

Where,
r=radius
n=blade quantity
C_L=lift coefficient
Λ=tip speed ratio
V_r=local resultant air velocity
U=wind speed
U_{wd}=design wind speed
C_{opt}=optimum chord length
Which is calculated as 0.052m=52 m?

2.4. Various Properties of material

Table.1 Material Properties

Material	yield strength(Mp)	Density(gm/m3)
Aluminium	276	2.7
Steel	415	8.05
Fibre plastic	60	1.45

By considering cost, availability, density and strength we selected plastic fiber material for our project.

3. Experimentation

3.1. Instruments Used

An axial flow blower named ADI-3 pressure blower 4800 cfm is used to for creating the air pressure. Selection of axial blower delivering 4800 cfm, power of 1 HP with 1440 rpm had been chosen for obtaining velocity of wind up to 7 m/s at exit the axial flow fan required 6.5 amp current and 240 V.A digital tachometer is used for the measurement of angular rotation of central shaft of rotor. Some arrangement has to be made for taking proper and accurate readings, a white colour radium sticker has to be placed over the central shaft and tachometer senses the radium while emitting red lights on the area of the radium. The readings displayed on screen either in revolutions per minute or revolutions of the shaft per second. This cup type anemometer is of mechanical type in which rotational speed of the central shaft will be measured with digital tachometer. This angular velocity is being converted into linear velocity on multiplying to the value of angular speed by radius of the anemometer. It is the most important instrument in measurement procedure. It is used to measure the voltage and current in windmill for single and multiple rotor as well as solar panel voltage.

3.2. Experiment procedure

For conduction of experiment, in case of blower test set up is arranged in closed room. Blower is arranged in front of the set up by varying distance, so that velocity changes. At different distance, velocity, voltage and current is measured and graph is plotted at different velocities and power, torque. The calculated velocity of flow, 7.47 m/s. From this experiment it concludes that, by varying distance of blower velocity of air flow is reduced as well as power.

4. Results & Discussions

Blower test has been carried on the model with varying velocity. Number of results has been obtained and with that result graphs has been plotted which differentiating the output of single rotor and multi-rotor

Single rotor Blower Test

First carrying the blower test on single rotor with five different velocity result has plotted on graph shown by fig, 2

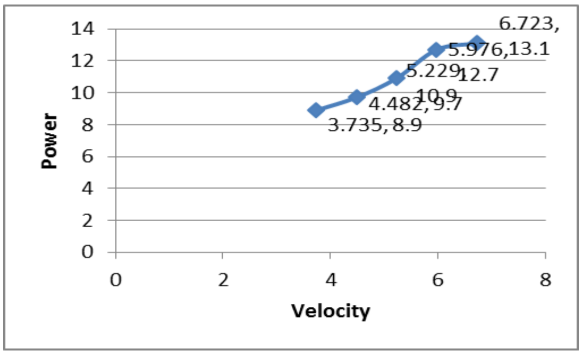

Fig.2 Power vs. Velocity of single rotor system

3.3 Rotor Blower Test Graph

Second test conducted on 3-rotors that gave five results plotted on graph shown by fig.3

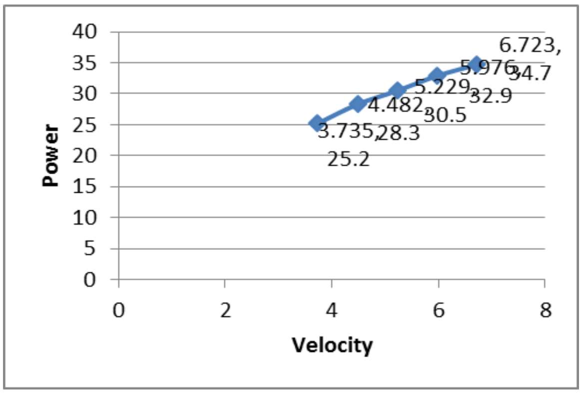

Fig.3 Power vs. Velocity of 3 rotor system

Conclusions

1) The new system has more wind power output, especially at lower wind speed. The performance of the new system can be enhanced by choosing small wind turbines with high power coefficient.

2) A three rotor wind turbine is designed to compare its cost and weight with a single rotor machine of equivalent capacity.

3) The main purpose of the MRWT is to reduce the overall cost of the machine. Despite the present limitations and the scarce literature available, the design provides useful predictions and allows inferences about the behavior of the system. With increased versatility, MRWTs could become useful in some applications.

References

Peter J. Schubel and Richard J. Crossley, (1996) Wind Turbine Blade Design, *Faculty of Engineering, Division of Materials, Mechanics and Structures ISSN 1073 ,University of Nottingham, University Park, Nottingham NG7 2RD, UK* ,4, 32-43.

Qunwu Huang , Yeqiang Shi , Yiping Wang , Linping Lu , Yong Cui, (2014), Multi-turbine wind-solar hybrid system, *b Tianjin University Research Institute of Architectural Design*, *34,4.*

Sandeep Kumar, Vijay Kumar Garg, (2013), A Hybrid model of Solar-Wind Power Generation System, *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE), 12, 4107-4016.*

Qiyue Song, (2012),Design, Fabrication, and Testing of a New Small Wind Turbine Blade, *The University of Guelph, Guelph,* Ontario, Canada,14,23-43.